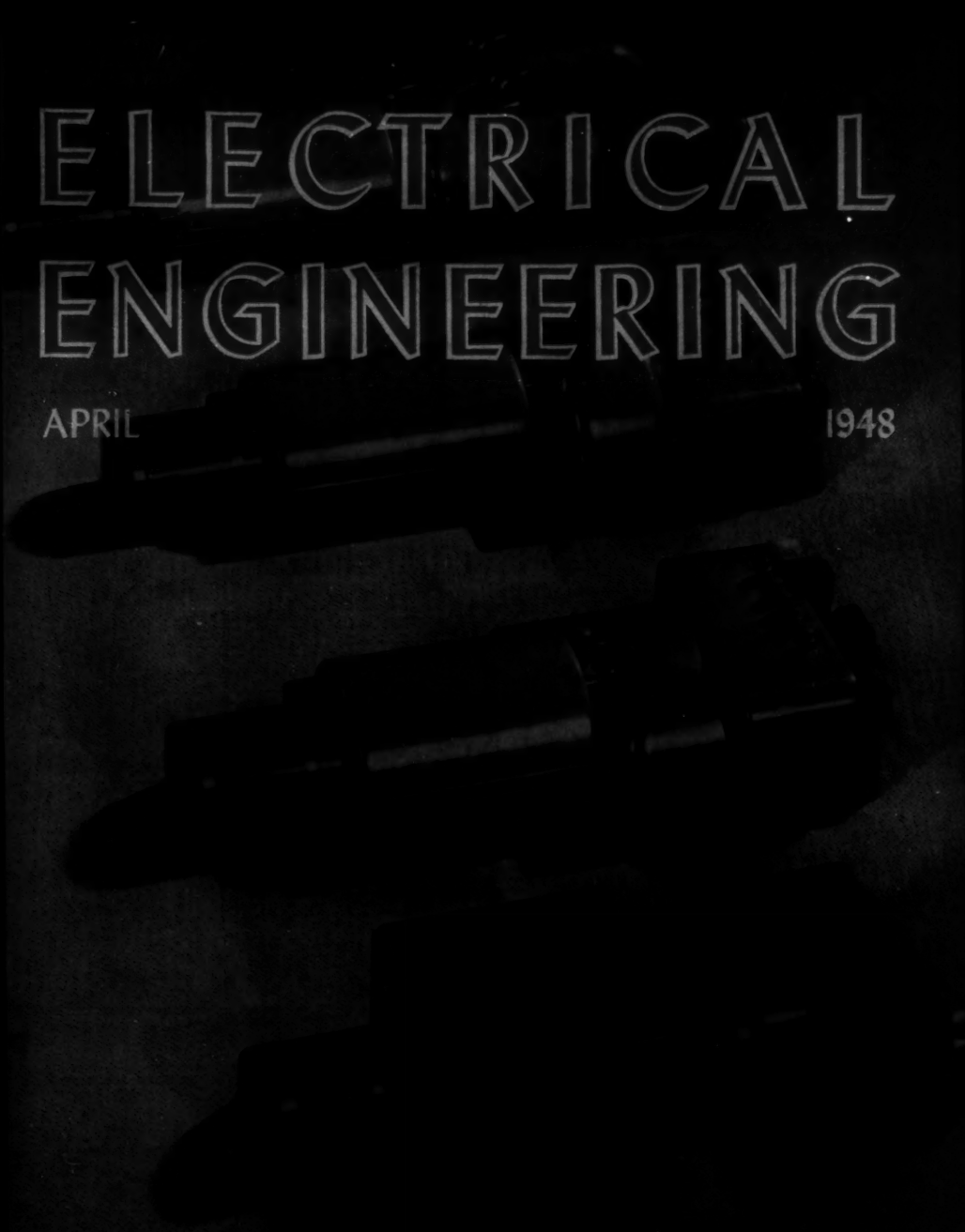
# ELECTRICAL ENGINEERING

APRIL 1948



AIEE NORTH EASTERN DISTRICT MEETING, NEW HAVEN, CONN., APRIL 28-30, 1948

# a SOLA CONSTANT VOLTAGE TRANSFORMER

## means the difference between success or failure in the performance of this instrument . . .

The BRUSH DEVELOPMENT CO. is another manufacturer that realizes that without the protection of "built-in" CONSTANT VOLTAGE, their Oscillograph, for recording strains, pressures and other electrical phenomena, could not maintain the precision on which its world-wide reputation has been founded.

With a "built-in" SOLA Constant Voltage Transformer maintaining operating voltages within ±1% of rated requirements, this instrument is ready to perform with consistent accuracy, anywhere, anytime.

Can you make the same claim for your product? Can you send it out with confidence that it can successfully cope with the unpredictable voltages that are prevalent on commercial power lines? Better investigate the possibility of adding a SOLA Constant Voltage Transformer to your equipment. It's not costly, you know.

There are standard types immediately available in capacities from 1 VA to 15 KVA—or, if these do not meet the requirements of your product, special units can be built to your specifications.

**SOLA** *Constant Voltage* **TRANSFORMERS**

**BULLETIN ACV-102**
*A complete handbook of voltage regulation—yours on request.*

**Transformers for:** Constant Voltage • Cold Cathode Lighting • Airport Lighting • Series Lighting • Fluorescent Lighting • Luminous Tube Signs Oil Burner Ignition • X-Ray • Power • Controls • Signal Systems • etc. • **SOLA ELECTRIC COMPANY, 4633 W. 16th Street, Chicago 50, Illinois**

*Manufactured under license by:* ENDURANCE ELECTRIC CO., Concord West, N. S. W., Australia • ADVANCE COMPONENTS LTD., Walthamstow, E., England
UCOA RADIO S.A., Buenos Aires, Argentina • M. C. B. & VERITABLE ALTER, Courbevoie (Seine), France

# ELECTRICAL ENGINEERING

Registered United States Patent Office

APRIL
1948

**The Cover:** These wooden models of steam turbines scaled three-eighths inch to one foot have been built by the Allis-Chalmers Manufacturing Company according to standards set forth by the AIEE and the American Society of Mechanical Engineers (AIEE Standards 601 and 602 which are scheduled for discussion in technical paper 48–110 at the AIEE Great Lakes District meeting in Des Moines, Iowa). Shown are models of units rated 11,500 kw, 20,000 kw, 30,000 kw, and 40,000 kw.

Allis-Chalmers photo

**Organization of an American Engineering Association**.....B. D. Hull . . . 313

**Wheatstone Bridge Applied to Train Braking**.....C. M. Hines . . . 317

**Electric Power and National Defense**.....Walker L. Cisler . . . 319

**Detection and Measurement of Nuclear Radiation**.....G. Wesley Dunlap . . . 325

**How to Price Political Liberty Out of the Market**.....R. W. King . . . 333

**The Heat Pump**

**The Utility's Perspective**.....S. W. Andrews . . . 338

**Significance as Potential Residential Load**.....Constantine Bary . . . 340

**Engine Drives**.....K. W. Miller, N. C. Penfold . . . 344

**Climatic and Usage Factors**.....D. W. McLenegan, G. W. Brown . . . 347

**X-Ray Thickness Gauge for Cold Rolled Strip Steel**.....W. N. Lundahl . . . 349

**Electrochemical Sources of Electric Power—I**.....George W. Vinal . . . 354

**Report on Industrial Voltage Requirements**.....AIEE Committee Report . . . 358

**Miscellaneous Short Items:**

British "Servo-Technique" Thinking, 318
Electrical Diamond Properties, 332
Electrical Essay, 337
Automatic Chemical Analysis, 353
A Magnetic Recorder for Power Systems, 357

**Institute Activities** . . . 375

**Of Current Interest** . . . 414

G. Ross Henninger
*Editor*
W. R. MacDonald, Jr.
E. E. Grazda
*Associate Editors*
F. A. Norris
*Business Manager*
J. S. Lopes
*Advertising Director*

VOLUME 67
NUMBER 4

**Statements and opinions given in articles and papers appearing in *ELECTRICAL ENGINEERING* are the expressions of contributors, for which the Institute assumes no responsibility. ¶ Correspondence is invited on all controversial matters.**

Published Monthly by the

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

*Founded 1884*

BLAKE D. HULL, President H. H. HENLINE, Secretary

PUBLICATION COMMITTEE: B. M. Jones, *chairman* M. S. Coover P. B. Garrett
H. H. Henline R. K. Honaman M. J. McHenry J. J. Orr H. H. Race C. F. Wagner

*ELECTRICAL ENGINEERING:* Copyright 1948 by the American Institute of Electrical Engineers; printed in the United States of America; indexed annually by the AIEE, weekly and monthly by *Engineering Index*, and monthly by *Industrial Arts Index;* abstracted monthly by *Science Abstracts* (London). Address changes must be received at AIEE headquarters, 33 West 39th Street, New York 18, N. Y., by the first of the month to be effective with the succeeding issue. Copies undelivered because of incorrect address cannot be replaced without charge.

# CREDENTIALS

## of the Newest Member of the Belden Magnet Wire Family

Celenamel magnet wire—newly developed by Belden—is copper wire insulated with a film of cellulose acetate combined under heat with other resinous materials. The film so produced is tough, flexible, continuous, and of high dielectric strength.

• • •

Celenamel is practically impervious to the action of hot coal tar as well as petroleum naphthas. The properties are such that Celenamel meets and in some respects exceeds industry standards for oleo-resinous enameled magnet wire.

• • •

In soldering operations it is unnecessary to remove the Celenamel insulation. Soldering of leads is accomplished by dipping in a low-temperature lead-tin bath or direct application of a soldering iron. A flux of rosin-alcohol should be used.

• • •

Celenamel films are produced with insulation additions that have closer and more uniform tolerances than have heretofore been available. The film withstands the usual temperatures encountered during coil impregnation and baking.

• • •

Celenamel insulation possesses very good aging qualities. Celenamel magnet wire produced several years ago still exhibits its original mechanical and electrical properties.

Celenamel is available in sizes 41 and finer.

**Belden**

**WIREMAKER FOR INDUSTRY**

# HIGHLIGHTS.....

**Future AIEE Meetings.** The AIEE North Eastern District will meet in New Haven, Conn., April 28–30. Ten technical and two Student sessions are scheduled, as well as inspection trips, entertainment, and a special program for the women (*pages 375–7*). A full-day technical conference on electrical problems, sponsored jointly by the AIEE subcommittee on rubber and plastics industries and the AIEE Akron Section, will be held in Akron, Ohio, April 30 (*page 375*).

**Mexico Meeting.** As preliminary plans for the summer general meeting in Mexico City progress, it is advised that persons interested in attending the meeting immediately return the request-for-information coupon (*EE, Feb '48, p 56A; EE, Mar '48, p 58A*) to receive desired information of transportation, hotels, and sightseeing (*pages 381–2*). In relation to these meeting plans, C. S. Purnell, chairman of the special meeting committee, recently spent a week in Mexico City in direct conference with the local general meeting committee there (*page 382*). On behalf of the Mexico Section, the chairman of the general meeting committee in Mexico City extends an invitation to Institute members to make the summer meeting a holiday in Mexico (*page 382*).

**Winter Meeting Sessions.** Because of space limitations, only a partial report of the 51 technical sessions held at the 1948 AIEE winter general meeting in Pittsburgh, Pa., January 26–30, could be accommodated in *ELECTRICAL ENGINEERING* for March (*EE, Mar '48, pp 272–96*). The report of the meeting is completed in this issue (*pages 383–404*).

**Year Book Publication Date.** Effective with the 1948 edition, the "AIEE Year Book" will be published and distributed in the early fall, probably September, instead of in the spring as has been customary (*page 377*).

**New Technical Digests.** As a further step to improve service to readers of *ELECTRICAL ENGINEERING*, hereafter comprehensive digests of the technical program papers will appear in place of the former very short abstracts which were published in meeting groups (*page 378*).

**Advance Pamphlet Price Change.** Advance pamphlet copies of technical program papers, formerly priced on a sliding scale based on the physical size of the individual paper, now are available at the flat price of 30 cents per copy to members, 60 cents to nonmembers, whether purchased from headquarters, or at the meeting (*page 378*). These prices became effective with the preprints for the Great Lakes District meeting as indicated with the abstracts of these papers published in the March issue (*EE, Mar '48, pp 265–6*). The price information in the customary explanatory paragraph accompanying the afore-mentioned abstracts, however, through an oversight was not corrected, and so should be disregarded.

**AIEE *PROCEEDINGS*.** The fourth *PROCEEDINGS* order form, for papers presented at the 1948 winter general meeting, appears on pages 49A and 50A of this issue (*page 401*). The AIEE *PROCEEDINGS* box gives the location of order forms appearing in previous issues, together with the meetings to which they pertain (*page 378*).

**Nuclear Radiation Measurement.** The fourth article of the series developed by the AIEE nucleonics committee is a summary of methods used for the detection and measurement of nuclear radiation. The series as a whole will be a valuable background for a basic understanding of this newest facet of engineering science (*pages 325–32*).

**National Engineering Association.** President Hull reiterates his belief in the necessity for the formation of an engineering organization representative of all engineers, an American Engineering Association. His proposal for a constitutional convention of all engineering societies to consider such an organization has been endorsed by the AIEE board of directors. Letters of comment on this subject are invited by the editor (*pages 313–17*).

**Power and Defense.** An adequate supply of electric power is essential to the preparation and carrying out of an adequate program of national defense, as has been proved so vividly by two world wars, just as it is essential to the maintenance of a healthy peacetime economy (*pages 319–24*).

**Politics and Science.** Is the loss of political liberty the price we must pay for increasing industrialization? The author warns us that we must understand clearly the many ways in which technology encroaches upon political liberalism, that not machine politics but machine-made politics should be our chief concern, for "in order better to comply with the demands of the machine, we unconsciously are fashioning our own political prison" (*page 333–7*).

**Heat Pump Opens New Horizons.** Varying and divergent views of the effect of the heat pump on residential heating practice were presented at a symposium led by M. M. Brandon (F '44) Underwriters' Laboratories, New York, N. Y., at the 1948 AIEE winter general meeting (*pages 338–48*).

**Industrial Voltages Reviewed.** The importance of proper utilization voltage is emphasized by the report of the subcommittee on industrial voltage requirements. An analysis is made of present practices and recommendations received from industrial electrical engineers. Recommendations are made for preferred voltage spreads, voltage ratings, and taps for industrial power transformers. The subcommittee will welcome comments (*pages 358–74*).

**Energy Source.** Part 1 of a 2-part article considering the electrochemical sources of electric power discusses the history of the battery. This article is one of a series appearing in *ELECTRICAL ENGINEERING* for the purpose of reviewing the various known methods of producing electric power (*pages 354–7*).

**Correction.** Two AIEE members who attended the winter general meeting in Pittsburgh find themselves misidentified in the photograph in the lower right-hand corner of page 281 of the March issue as the result of a printer's error. C. F. Wagner (F '40) of the publications committee appears, of course, at the left of this photograph, while Lloyd F. Hunt (F '38) Southern California Edison Company, Ltd., is at the right.

## News Index


**Institute Activities.....375**

North Eastern District Meeting.....375
Year Book Publication Date.....377
Advance Pamphlet Prices.....378
Technical Paper Digests.....378
AIEE *PROCEEDINGS*.....378
Future AIEE Meetings.....380
Summer General Meeting.....381
Winter General Meeting Report (conclusion).....383
Personal.....404
Obituary.....407
Membership.....408

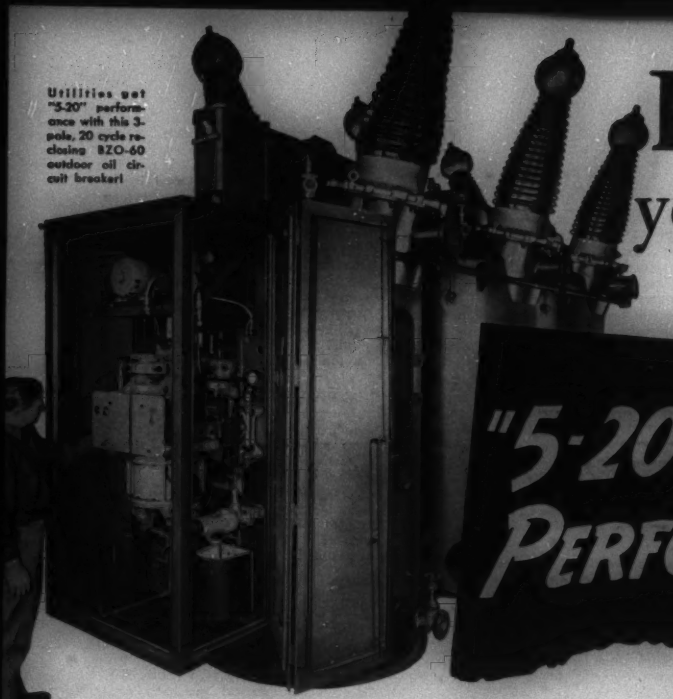
**Of Current Interest.....414**

1947 Book List.....414
Honors.....417
Other Societies.....418
Future Meetings of Other Societies.....419
Education.....419
Joint Activities.....420
Letters to the Editor.....420
New Books.....421
Pamphlets.....422

**Industrial Notes.....14A**
**Trade Literature.....36A**
**New Products.....58A**
**PROCEEDINGS Order Form..49A, 50A**



ELECTRICAL ENGINEERING. Published monthly by the American Institute of Electrical Engineers; publication office 20th & Northampton Streets, Easton, Pa. Editorial and advertising offices 500 Fifth Avenue, New York 18, N. Y. Subscription $12 per year plus extra postage charge so all countries to which the second-class postage rate does not apply; single copy $1.50. Entered as second-class matter at the Post Office, Easton Pa., under the Act of Congress of March 3, 1879. Accepted for mailing at special postage rates provided for in Section 538, P. L. & R. Act of February 28, 1925 April 1948, Vol. 67, No. 4. Number of copies of this issue 45,000



Utilities get "5-20" performance with this 3-pole, 20 cycle reclosing 8ZO-60 outdoor oil circuit breaker!

# Protect your system with...

# "5-20" BREAKER PERFORMANCE!

## Allis-Chalmers Outdoor Oil Circuit Breakers Rated 115 kv and Up, Now Equipped with New 5-Cycle "Ruptor" and Pneumatic Operator!

INTERRUPTION IN 5 CYCLES... reclosing in 20—that's "5-20" breaker performance. It means *added stability* for your high voltage lines... safeguards *continuous service* for your *customers*... provides *best protection* for all concerned!

For breakers themselves, "5-20" performance means *greatly minimized contact wear, less oil deterioration.* It assures minimum arc energy release and low tank pressures.

If you're planning system expansion that calls for new breakers, you will want to get the *full* story on Allis-Chalmers "5-20" breaker performance.

Proved by almost 15 years of operation on breakers rated 7.5 kv and up, you can expect such benefits as:

☛ Contact Simplicity—single-break contact design—with reliable, high-speed performance.

☛ High Arc Quench Efficiency—"Ruptor" device (single-break with 2 units per pole) snuffs out heavy short circuit arc within 0.055 of a second from parting of contacts.

☛ Quick Contact Inspection—easy removal of "Ruptor" shell unit exposes contacts. Operation may be checked by manual closing of breaker.

For complete information on 5-cycle "Ruptor" equipped (115 to 230 kv... 1,500,000 to 3,500,000 kva) or other breakers to meet your requirements, call your nearby A-C Sales Office, or write ALLIS-CHALMERS, MILWAUKEE 1, WIS.

### PRINCIPLE OF "5-20" BREAKER PERFORMANCE EXPLAINED

NEW 5 CYCLE dynamic (single break) "Ruptor" includes 2 devices per pole. "Ruptor" limits arc energy release... helps to maintain dielectric strength of oil in tank. Electrostatic shield, left, increases insulation factor between contacts and tank.

1—Like arrows from a bow, contacts open lightning-fast upon release of stored energy in powerful accelerating springs!

2—Like a tornado, pressure created by arc swirls oil through helical throat, developing great oil turbulence in "Ruptor"... quenching arc and clearing arc path... interrupting circuit in 5 cycles or less from energization of trip coil.

3—Ultra-rapid pneumatic operator recloses breaker within 20 cycles.

A 2184

ALLIS-CHALMERS

A CENTURY OF SERVICE to Industry THAT MADE America Great

# Organization of an American Engineering Association

B. D. HULL
FELLOW AIEE

THE FORMATION of an engineering organization representative of all engineers has been the subject of much discussion during the past year but it is a subject which will bear repeated discussion. I wish I could report that some form of engineering association was on its way to accomplishment, but such is not the case. If it were a matter of only the electrical engineering group, the difficulties would not be so great as to preclude the possibility of reaching a common ground in the very near future. However, the problem is much more complex—it involves creating interest not only among the electrical, but also among the civil, mechanical, mining, chemical, and all the other branches of engineering in the organization of a society to meet the professional needs of all engineers.

First, however, I wish to summarize some facts that bear on this subject. One prominent American engineer in a paper delivered before the International Technical Congress in Paris last September, has said of the engineer of the United States:

> The engineer of the United States of America is a vital factor in the life of his nation. He changes its economy and modifies the customs and social habits of its people. He is an idealist and a dreamer. He is a realist and a doer. He co-operates with his colleagues in technology but is impatient with politics. He frequently is charged with lack of understanding of the social effects of his work. He is modest of his talents and likes to be called to high places rather than aggressively press the crowd for position. This results in some places in an undervaluation of his services. He has the traits common to human beings, as is shown by the organization of his profession, but his work is good and he does have a high sense of professional responsibility.

This describes the average engineer particularly well. We are good engineers but we need more of the qualifications necessary to sell our profession. We are content to stick to our knitting and to let the rest of society control our destiny. This situation, fortunately is changing.

An address presented at a joint session of the AIEE and the National Electronics Conference during the AIEE Midwest general meeting, Chicago, Ill., November 5–7, 1947, and variously presented before other AIEE gatherings.

B. D. Hull, AIEE president for 1947–48, recently retired as chief engineer, Southwestern Bell Telephone Company, St. Louis, Mo.

**The AIEE board of directors has endorsed President Hull's proposal for a constitutional convention of engineering societies toward the objective of establishing an appropriate joint national engineering organization "to deal with the social, economic, and professional problems common to all engineers," and has taken action providing for the AIEE to participate in such a convention. This subject is believed to be of some direct concern to every member of the Institute. Its discussion by Section and other groups is suggested, so that membership opinion may evolve and Institute officers be guided accordingly. Comments are invited for the "Letters to the Editor" columns.**

What we need, of course, is a vigorous professional consciousness on the part of each individual. You and I must take pride in our work, pride in the fact that we are professional engineers who have done as much, if not more, for the welfare of society as any other group. Unless we are convinced that ours is a profession equal to medicine, to law, to the ministry, we will have little success in convincing others.

How to arouse and promote this consciousness of professional worth has been the subject of a vast amount of discussion. Being engineers we have sought an engineering solution; that is, we have striven for a practical formula which would solve the problem in one simple process. It has been suggested, for example, that all we need is the right kind of a definition of what is an engineer. Another approach is the requirement that all engineers should be registered and so we become a prideful and honored profession. Obviously none of these or any other similar approach is the whole answer. Professional consciousness usually follows but does not precede professional unity. We need look only to the history of the older professions to appreciate this. Any strongly organized professional group which vigorously promotes the interests of its members and actively discharges their obligation to society need not worry about professional consciousness. It will take care of itself. All of this agitation within our own group of electrical engineers to find the right kind of organization probably already has done much towards arousing a feeling of professional awareness.

During the past few months I have read several articles written by prominent engineers, most of them past presidents of the civil, mechanical, mining, and electrical, engineering societies, and I find that as far back as the 30's, and even earlier, they recognized the need of raising the profession of engineering to its proper level in society and some effort was made towards a national engineering society to improve the situation.

The feeling is almost unanimous that, in general, the existing engineering societies—in spite of some overlapping and duplication—are carrying out their technical functions extremely well and with a reasonable degree of efficiency. Where this is not the case, I believe that they have within their own organizations sufficient capacity and authority to expand such technical activities to whatever extent is needed.

## PROFESSIONAL DEVELOPMENT

With respect to the engineer's professional development, improvement of his economic status, his responsibility to society, in short, all interests outside of his strictly technical preoccupation, the existing technical societies by their very nature individually are inadequate. The reason for this stems from the fact that these are all matters that require co-operative action by all engineers and not by one group acting alone, or by several groups working at cross purposes.

At the present time there is no engineering organization with sufficient authority to care for the engineer's professional development. There are several societies and agencies that represent specified groups of engineers or attempt to represent all engineers.

One of the first to organize for this purpose was the American Association of Engineers, organized in 1915 to promote the social and economic welfare of engineers, to stimulate public service in the profession, and to encourage and develop the efficiency of the engineer. It did not have the proper backing of the national technical societies and, while it still exists, its membership is very limited.

The National Society of Professional Engineers, organized in 1934, is intended to represent those engineers who are registered under the various state laws. This society is doing a good job in its field but, because of its limitation as to membership, can speak at present for only a relatively small per cent of all engineers. Ultimately all engineers may be registered, but this is not at all certain to come about.

An organization which is supposed to represent a large number of engineers is the Engineers Joint Council. The EJC has been in existence for the six years since the demise of the American Engineering Council, but it is handicapped, in my opinion, by two factors. First, it is made up of only the four founder societies—civil, mechanical, mining, and electrical—and, in addition, chemical. Consequently, it cannot speak for all engineers. Second, its membership is not composed of individual members of these societies but only of the president, past president, and secretary of the five participating societies. It has very limited authority of its own and only the most indirect ties with the individual engineer. If I could ask how many know what EJC is and what it accomplishes, I am sure the response would not be very great. In spite of its handicaps, however, EJC has been doing a good job.

Another organization which should be mentioned is the Engineers' Council for Professional Development which is doing a fine piece of work in its field, but is capable of only limited activity in the field under discussion. An appointed body, it cannot represent the individual engineer, who has no voice in its selection or in forming its policies.

There are other organizations, and probably some with which I am not familiar, working toward the same end; that is, raising the professional status of the engineer—but, if the job is to be done effectively, it will require a combination of all such organizations under one society.

## COLLECTIVE BARGAINING

The need for a professional engineering organization is clearly evident to all who have observed the trend of events for the past few years. There has been a restless stirring among young engineers, both inside and outside of the technical societies. We have seen evidence of this in many instances. Their intense preoccupation with the problem of unionization is significant. While most of them reject the plan of craft or other forms of unionization as now is practiced, there is a growing feeling on the part of the young engineer that some form of professional organization is needed to represent them collectively.

While it is not the function of either the present technical or professional engineering societies or the proposed American Engineering Association to act in a bargaining capacity for any group of engineers, there is a crying need for a more sympathetic understanding on the part of the more mature engineers who naturally dominate the professions.

I have noted with particular interest the activities of a group of younger engineers who are members of the New York section of American Society of Mechanical Engineers, a group in whose efforts the AIEE New York Section is participating. I hold no brief for what they are proposing—it may be good or wholly impractical. I do recognize, however, that there is a spirit of mild rebellion, a feeling of frustration with the present situation with its lack of united effort to improve the engineer's professional status, which, if not met, easily can lead to alienating the present loyalties of large groups of engineers. I am certain that no organization, not even the proposed American Engineering Association, made up as it will be of both employer and employee, could perform the function of a bargaining agent, but it would serve to bring into the open all differences and foster a

closer co-operation among us. It seems to me this is a concrete and pressing example of a need for a national organization which constructively can undertake the solution of this problem.

Another example of the need of an effective organization for raising the profession of engineering in the eyes of society is the treatment accorded engineers during the last war. A doctor or a dentist, when drafted into the Army, was given a rank of first lieutenant at least. The graduate engineer, when drafted into the Army, could be taken in as a third class private.

## GROUP RESPONSIBILITY

Thus far this article has related only to the professional advancement of the individual engineers. The group responsibility of the engineering profession to society is the second and equally important phase of the problem that calls for unified action. The thing that distinguishes a profession from other groups working only for self-advancement is its sense of responsibility to all of the people. The engineering profession needs a vehicle such as that proposed to discharge this responsibility successfully. An attempt to obtain the necessary co-ordination of effort at the local level by the formation of engineering councils has been rather successful in some instances. Where the individual engineer actively is involved in such organizations and kept in close touch with its activities, such councils are a success. Unfortunately, in too many instances, the councils are so remote from the individual engineers that they are hardly aware that they exist. Even if the local councils can be made to work, there still are lacking vigorous organizations at state and national levels, drawing their strength from individual membership.

The need for some professional organization was recognized by the AIEE during the administration of the late Doctor Wickenden. He suggested to the planning and co-ordination committee that the whole field of intersociety relationship be studied. Mr. Fairman, chairman of that committee, promptly appointed a subcommittee to devote itself to the broad objective of finding an organization through which all engineers more adequately could develop their professional welfare and discharge their responsibilities to society. The committee has made its report and recommendation based on the sampling of the opinion of members of the Institute in all parts of the United States. The subcommittee's report was submitted to a committee of the past presidents of the AIEE for review and was published in the May 1947 issue of *ELECTRICAL ENGINEERING* (*pp 496–500*). I urge all those who have not read this report to do so.

I do not wish to present a lot of statistics, but I do believe we should grasp the significance of the sampling polls summarized in the subcommittee's report. Approximately 90 per cent favored some change in organization of the engineering profession. The plan for an American Engineering Association definitely was favored above all other plans. The plan which received the next highest approval provided for an extension of the local council or federation idea. It is significant that the latter plan was considered in a great many instances as a practical approach to the ideal plan of an American Engineering Association. In other words, many engineers who favored an American Engineering Association selected some other plan as first choice merely because they considered the American Engineering Association an ideal which could not be attained immediately.

I believe that similar polls taken among other engineering groups would produce substantially the same results. The significance of this is that many engineers, recalling past failures, are apprehensive that the ideal organization cannot be attained, but that we must be satisfied with something not quite as good. That I do not believe is true now. The urge for and the need of a strong centralized body is so paramount that former obstacles no longer will be controlling.

There are many differences of opinion and conflicting views as to how the objective of a national engineering association can be accomplished, but I am satisfied that the majority of the members of the Institute are in favor of an organization such as the one proposed, or some similar setup.

The name, "American Engineering Association," is a type name chosen by the subcommittee to indicate the character of the proposed organization rather than a specific recommendation. I do not propose to review the report of the committee, but I do wish to emphasize a few considerations which I believe are fundamental to any form of an inclusive organization.

There has been some misunderstanding concerning the effect of the proposed organization on the existing national technical societies. This has resulted principally from our inability to cover adequately all phases of the matter in a brief summarizing report of this kind. Naturally some misinterpretations and erroneous conclusions could be expected. One such misinterpretation which I wish to correct is that the plan does not propose in any manner to interfere with, curtail, surrender, or injure any of the technical activities of the individual societies. Perhaps the type of charts used in the draft is partly to blame. It is not as clear as it might be, again because of the dictate of brevity.

To repeat again, an American Engineering Association must preserve intact and allow for complete freedom of development of the existing technical societies as originally conceived. Despite some duplication and overlapping, these societies are carrying out their primary purpose of fostering and spreading scientific and engineering knowledge with reasonable effectiveness. Any interference with these basic functions by a national over-all organization would serve no useful purpose.

However, while maintaining all of their technical

activities unimpaired, it will be natural for the national technical societies to transfer to the American Engineering Association certain of their nontechnical activities. These represent activities of long standing which it will be difficult to give up. It represents, perhaps, the hardest part of the job of getting together, but, unless it is done, that co-operation, that co-ordination of effort, that unity of action which we must have to accomplish the purpose, will be impaired. It need not be done all in one stroke but, little by little, as facts and understanding develop. I believe our survey of the membership opinion has given proof that AIEE members are ready to make the moves necessary to accomplish the proper end result, and, what the AIEE is prepared to sacrifice, I am sure the other engineering societies also are prepared to do.

## ORGANIZATION

Another point I wish to make, and which the proposed setup recognizes, is that any organization of the kind under discussion must begin at the bottom and work up, and not at the top and try to work down. It must be based on individual membership.

One of the difficulties with some organizations is the remoteness of the governing body from the individual engineer. The engineer pays no direct dues for support of the organization and gets no reports of its activities. The American Engineering Council failed in 1940 because two of the supporting societies gave notice of their intention to withdraw their support. Had it been made up of individual engineers, this probably could not have happened. Further, such individual members must be associated locally in a strong society or council. The organization will succeed or fail depending entirely upon the strength of the local bodies.

From the local bodies, a rather simple line of representation can be established through regional or state societies to the national body, or directly, if found to be more effective. The individual member must be the basic unit, however. Unless the national body is supported and nourished by the roots of individual members acting through local bodies, it inevitably will wither and die.

Finally, a set of uniform grades and qualifications for membership must be adopted by all participating societies and apply also to individual members not belonging to any of the participating societies. The subcommittee report outlines suggested qualifications. This matter is under study by the Engineers' Council for Professional Development and we can hope that constructive action in that direction will be taken soon.

"Who's Who in Engineering" lists some 70 or more national engineering societies and societies with activities relating to engineering. It is estimated that there are more than 250,000 persons in the United States, or one in every 525, who call themselves engineers. Many of these individuals would not qualify as engineers under any reasonable set of standards and such persons should not be considered eligible to join a national engineering association. What each technical society wishes to do about such candidates for entrance into its own society is a matter for each to decide, but the qualifications for the American Engineering Association must be uniform regardless of the technical branch to which the individual belongs.

I have presented a suggested organization picture as it seems to me. On one side, the existing technical organizations functioning as they do now on technical matters and tied in to the American Engineering Association by representatives of their own choosing, the number to be based on total membership. On the other side, an organization similar to the setup of the National Society of Professional Engineers, but including all engineers having certain definite qualifications reporting through local and state councils to the governing body of the American Engineering Association. This side of the organization would handle all of the nontechnical problems of the engineer not common to a single group.

I do not underestimate the problem of organizing an American Engineering Association and the difficulties to be overcome in drawing up a workable, satisfactory form of organization. It will not be an easy task and it cannot be accomplished quickly, but it is high time that positive steps be taken.

I have heard many engineers say that in their opinion it will be impossible to get a group of engineers to agree on anything that is not based on a scientific fact. Practical, unscientific, and organization matters, even politics, are subjects at which he is not adept. Therefore, I wish to refer to some early American history with which everyone is familar. During the Revolutionary War, there were many differences of opinion and a general lack of co-operation among the several states. None wanted to give up their ideas and state rights. With the end of the war, the last semblance of united effort disappeared and there followed a period of veritable anarchy. Among the states, rivalries and jealousies ran rampant. By May 25, 1787, the widespread friction, economic chaos, and threatened disintegration had become so acute that a Constitutional Convention was called in Philadelphia. Out of this came the Constitution of the United States; not dropped down like a scroll from Heaven, but the product of a bitter struggle between jealous states and the conflicting views of able statesmen. How much simpler are our problems than were theirs.

I believe that a few representatives of the major engineering societies—men familiar with the needs of the engineers, conscious of the profession's obligations to society, its obligations to the individuals, experienced in the affairs of existing engineering societies, men who are willing to work co-operatively—should be brought together in a sort of constitutional convention to draw up a plan for submission to the existing societies. The need for a union of some sort is urgent. That need is under-

stood thoroughly by our membership as shown by the polls. I am sure the same feeling prevails among all engineers. With that incentive I am certain that a union can be worked out.

Summed up, the need for such an organization seems to me to be very clean-cut. There should be no further delay in taking a realistic look at what has happened and what is continuing to happen to the position of the engineering profession. To do this, we must interest the other societies in taking this matter seriously. I do not think this will be difficult. No one is going to destroy any other organization's work but simply transfer it to a new organization of which that organization will be a part. In other words, we all are going to unite for our common good. We must arrive at a type of organization which will reflect the will of the majority of the membership.

Comments, ideas, and criticisms will be welcome. With the active co-operation of the other national technical societies, Engineers' Joint Council, National Society of Professional Engineers, Engineers' Council for Professional Development, joint local meetings, and personal contacts, I think there can be created such enthusiasm for such an organization that the national societies and others who qualify will be ready to appoint representatives to what might be called a constitutional convention to draw up a constitution and bylaws for such an organization. Certainly, if our forefathers could get together and settle their extremely important affairs, the engineers should be able to settle their much less important differences. Then, with 200,000 engineers speaking as one voice on their professional problems, many things could be done which are now impossible.

# The Wheatstone Bridge Applied to Train Braking

C. M. HINES
MEMBER AIEE

**General information is given about a new scheme for indicating change from a balanced condition which can be used with any type of bridge circuit. The method is one which checks its own integrity and lends itself to applications demanding rugged apparatus, long life, and a minimum of maintenance.**

THE "pneumatic brakes" on most modern high speed trains normally are controlled electrically with pneumatic control standing by in reserve. In such an electropneumatic system, a pneumatical operated master controller is equipped with contacts which supply energy by means of train line wires to application and release magnet valves, one pair being on each vehicle. All application magnets are in parallel and all release magnets are in parallel, a common return being used for both sets of magnets. Although the emergency brake may be used in case of failure of an electric circuit, it is much more desirable to know of the failure in time to transfer to the conventional automatic air brake before a brake application is necessary.

After making tests with numerous methods for indicating abnormal brake circuit conditions, it finally was decided that the use of the Wheatstone bridge was the solution. This old stand-by presents a ready means for accurately measuring the resistance of the magnet valves and the train line wires which control them and so could be used to indicate any change in resistance resulting from open circuits or short circuits. The disadvantage of using the Wheatstone bridge lies in the fact that a null indication represents a balanced condition. Therefore, a fault such as an open lead to the galvanometer in the Wheatstone bridge would indicate a balanced condition, and a fault in the brake system would not be detected.

One unique feature of the system finally adopted lies in the means for converting the Wheatstone bridge into a device which checks its own operation as well as indicating any change in the condition of the circuits

Essential substance of paper 48-53, "A Unique Application of the Wheatstone Bridge to High-Speed Train Braking," presented at the AIEE winter general meeting, Pittsburgh, Pa., January 26-30, 1948, and scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

C. M. Hines is an electrical engineer with the Westinghouse Air Brake Company, Wilmerding, Pa.

The author wishes to acknowledge the work on bridge circuits in hot box detectors done by G. W. Baughman (M '45) and A. B. Miller of the Union Switch and Signal Company, Swissvale, Pa.

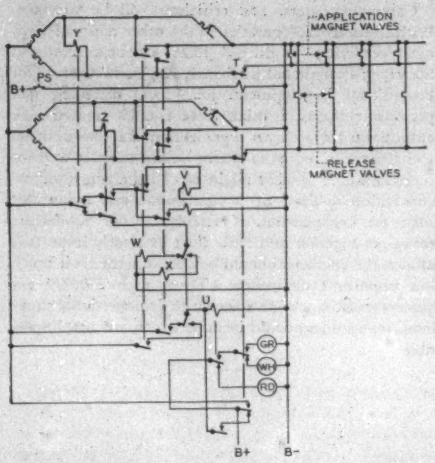



**Figure 1. Schematic diagram of circuit checking equipment**

*T—Control relay*
*Y, Z—Detector relays*
*U, W, X—Time delay relays*
*V—Polarity relay*
*GR—Green light*
*WH—White light*
*RD—Red light*
*PS—Pneumatic switch*

whose resistances are being measured. Figure 1 shows schematically the circuits involved in the system and all devices are shown in the de-energized position, it being assumed that the battery supply is open.

Two bridges are used, one for checking the application wire circuits and the other for checking the release wire circuits. The galvanometer usually associated with the Wheatstone bridge is replaced by a relay. In addition to detector relays $Y$ and $Z$, three additional relays are used for controlling the bridges. Relays $W$ and $X$ are used to short-circuit, alternately, one of two arms of each bridge. The third relay $V$ is of the polarized type in that the position of its contacts is controlled by the direction of current flow through the coils. The contacts of this relay control the $W$ and $X$ relays to select which one is operated. Relays $Y$ and $Z$ will detect a change in resistance which is evidenced by an unbalance during a complete operation of $V$. (That is, the resistance of the alternately short-circuited arms is compared by the bridge and detection lies in failure of one or both of relays $Y$ and $Z$ to drop out following removal of the short circuit.) The sixth relay in the system, relay $T$, is used to disconnect the circuit checking equipment from the application and release wires during a brake application and to indicate that the brakes are applied. The seventh relay $U$ controls the light indication or other means to warn the engineman of faulty circuits.

Sensitivity to change in resistance can be made as desired. For the type of service being described, it is felt that detection of changes of ten per cent are adequate, and that higher degrees of sensitivity would result in unnecessarily switching from the electropneumatic brake to the automatic brake with the consequent loss of the advantages of the former system.

The bridge is self-checking and will give a "fault" indication in event of any failure in the bridge itself.

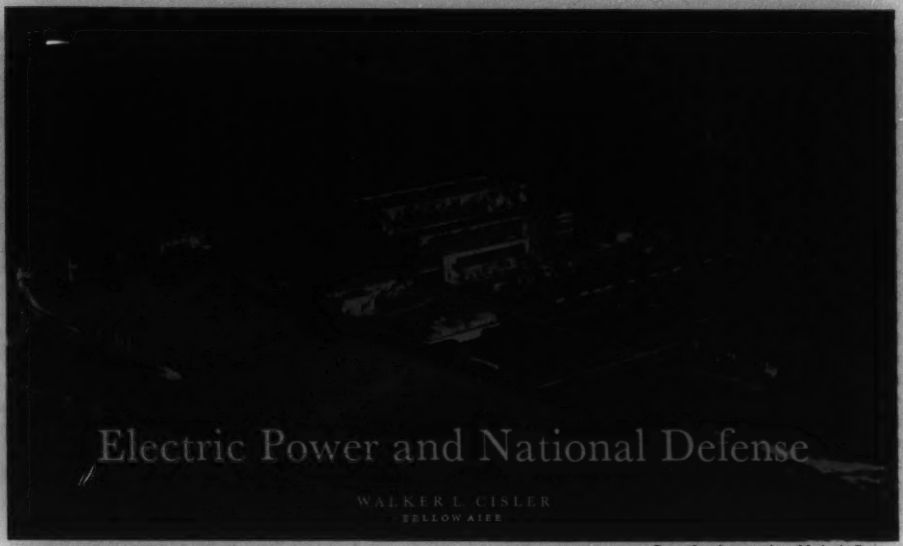
The dials of the rheostat knobs are calibrated from 1 to 24 vehicles. The engineman, after determining that the electropneumatic brake is functioning properly and knowing the number of vehicles in the train, then can proceed to set the rheostats. These calibrated dials also are a great help in locating the source of trouble in the frequent instances of faulty jumper connections between cars or other open circuits.

## British "Servo-Technique" Thinking

A recent issue of *Electrical Review*, a British technical journal, reviews a paper that was presented before the Association of Supervising Electrical Engineers by F. E. Butcher, Electro Methods, Ltd., on a war-born art called "servo-technique." He believes that this field (known in the United States as "servomechanisms") will have a profound influence on future control problems.

He believes the electronic amplifier will be superseded by the magnetic amplifier, a development of the saturable reactor, that can perform functions not easily carried out by electronic amplifiers, with greater reliability. It could be used as a d-c amplifier, or as a d-c to a-c inverter-amplifier, and would accept and mix a number of d-c signals completelyisolated from each other and the output circuit.

Another useful accessory in control circuits mentioned was the "mess" motor (an abbreviation of the German *messung*, meaning measurement), in which, so far as was possible, factors likely to affect the linearity of the voltage-speed curve were eliminated. The resulting accuracy was of such an order that these motors could be used to integrate minute voltages on a time basis. By using a suitable transducer for converting temperature or temperature difference into a voltage signal, the "mess" motor could integrate over a time and apply the result instead of relying upon instantaneous readings with the smaller available power. A demonstration was given where the "mess" motor was run directly from a photoelectric cell and a thermocouple.




Camouflaged power plant, Marback, Germany

**The importance of electric power has been proved dramatically by two world wars, and it will play no less a vital part in any future conflict. On the basis of the record, the author strongly emphasizes the necessity for co-operation between the Department of National Defense and the electric power industry to ensure the maintenance of adequate reserves for the production of electric power in anticipation of future threats to United States military safety and security.**

ELECTRIC POWER in its relation to our national defense is a subject of great concern, a matter of solemn responsibility, to everyone in the electrical utility industry. It is, or should be, a subject of deep concern to all Americans as it reaches into almost every home, business establishment, and industrial enterprise. The history of the two great world wars has proved dramatically the vital part of electric power: literally speaking, those who won had enough; those who lost, not enough. It will be equally true in any future conflict in which we may be forced to engage.

In this article, the author wishes to make it perfectly clear that he is submitting his own personal views and experience, which do not necessarily reflect the thinking of others who may be equally, or more, informed about the subject. His purpose is to present a broad general view of the topic and to point out some of the things we ought to be thinking about in planning for the future.

The United States has become great and strong for three main reasons. It is well that we always keep these in mind.

The first reason for our advancement is our democratic form of government which our forefathers so wisely laid out for us. It is a heritage which we must guard jealously against weakening influences, both from within ourselves and from without. It is our greatest asset.

The second reason for our development and strength, is that nature endowed the United States with vast natural resources. These are being used at a fabulous rate and they must be conserved by the avoidance of waste and unwise usage, for already we find that certain reserves have a foreseeable depletion, notably timber, some of the metals, and liquid and gaseous fuels.

The third reason for our position as that of the strongest industrial nation and the nation which has the highest standard of living is brought about by our capacity for industrial production, our "know-how," our ability to get things done in industry such as no other nation ever has attained. A great part of our future strength depends upon these "industrial assets,"

Essentially full text of a conference paper, "Electric Power and Our National Defense," presented at the AIEE winter general meeting, Pittsburgh, Pa., January 26–30, 1948.

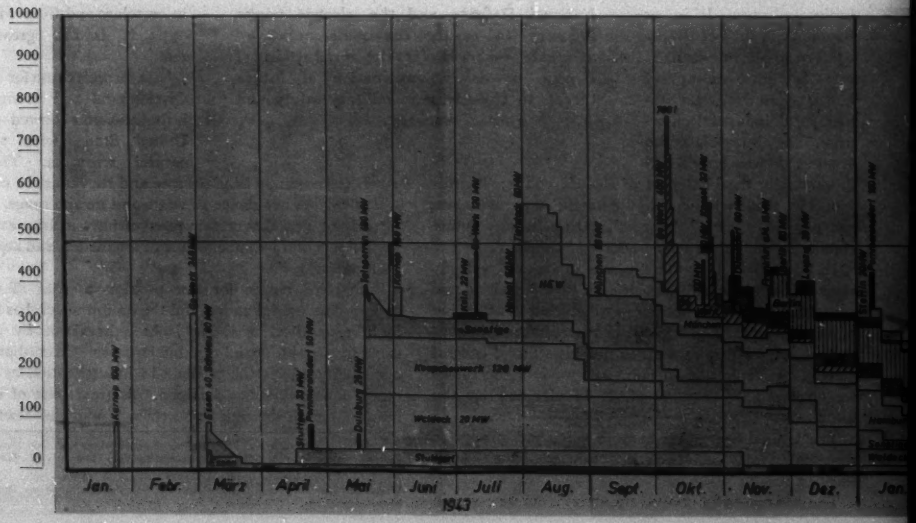
Walker L. Cisler is executive vice-president, The Detroit Edison Company, Detroit, Mich.

and their productive component, electric power, is a basic ingredient.

What electric power made possible in the last war is known in a casual way to millions of Americans. It was never too little or too late in the United States. No group more fully met its patriotic responsibility and duty than did our utilities. Many times those of us who were in war zones gave devout thanks for this as we watched great unending streams of supplies and equipment rolling forward to the front. It gave to the nations with which we were allied a visual sense of strength and formidableness which was almost beyond comprehension because of its size and scope. It caused those nations and people to feel that their own future strength basically was tied in with and dependent upon a development of their own industrial capacity, and as a part of this, upon the development of their electric power resources. In view of this, it is understandable that the requirements presented by the 16 nations of Europe under the Marshall Plan include an ambitious and highly desirable program for the expansion of their electric power resources. Such a program calls for the addition of about 24 million kilowatts of new generating capacity during the next five years. It cannot be achieved within that time as it probably would require years more to complete because of a number of factors such as capacity of and wartime damage to manufacturing plants, and lack of manpower, materials, fuel, and transportation. It is, nevertheless, important from our national defense standpoint that these nations be strong industrially, and to be so, they must have adequate electric power resources even though it will take longer to complete the program.

## IMPORTANCE IN PEACETIME

Let us consider for a moment the importance of electric power to our peacetime economy, because a healthy peacetime economy is essential to maintaining a strong national defense position. The United States' electric power industry today is engaged in the greatest expansion program of its history to make up for what could not be added during the war and to meet postwar load increases. During the next five years it will construct and put into operation more than 18 million kilowatts of new capacity in public and private plants. If we add to this the existing 52 million kilowatts and more of capacity on the utility systems, we arrive at a total of more than 70 million kilowatts—an amount far greater than that of any other nation. If to this then is added the present 13 million kilowatts of capacity represented by industrial, transportation, and other plants, plus that which will be added during the next five years to these same classifications, we find that the American domestic, commercial, and industrial user of electric power will have at his command the greatest pool of power that man ever has known. In general terms, the United States produced in 1947 more than 300 billion kilowatt-hours of electric power—an amount in all probability equal to the rest of the world combined. It represented energy consumption to the extent of more than 2,000 kilowatt-hours per capita per year.



Looked at broadly, this ability to produce and consume electric power in such amounts forms one of our most formidable strategic weapons for both our defensive and offensive requirements.

## NEED FOR CO-OPERATION

In planning our peacetime expansion program, we must not lose sight of what our needs may be in preparing for a future conflict using equipment and weapons of far-reaching significance. This is an aspect of our expansion in the consideration of which we should be influenced by the advice of those who are directly responsible for the military advances of the country. With

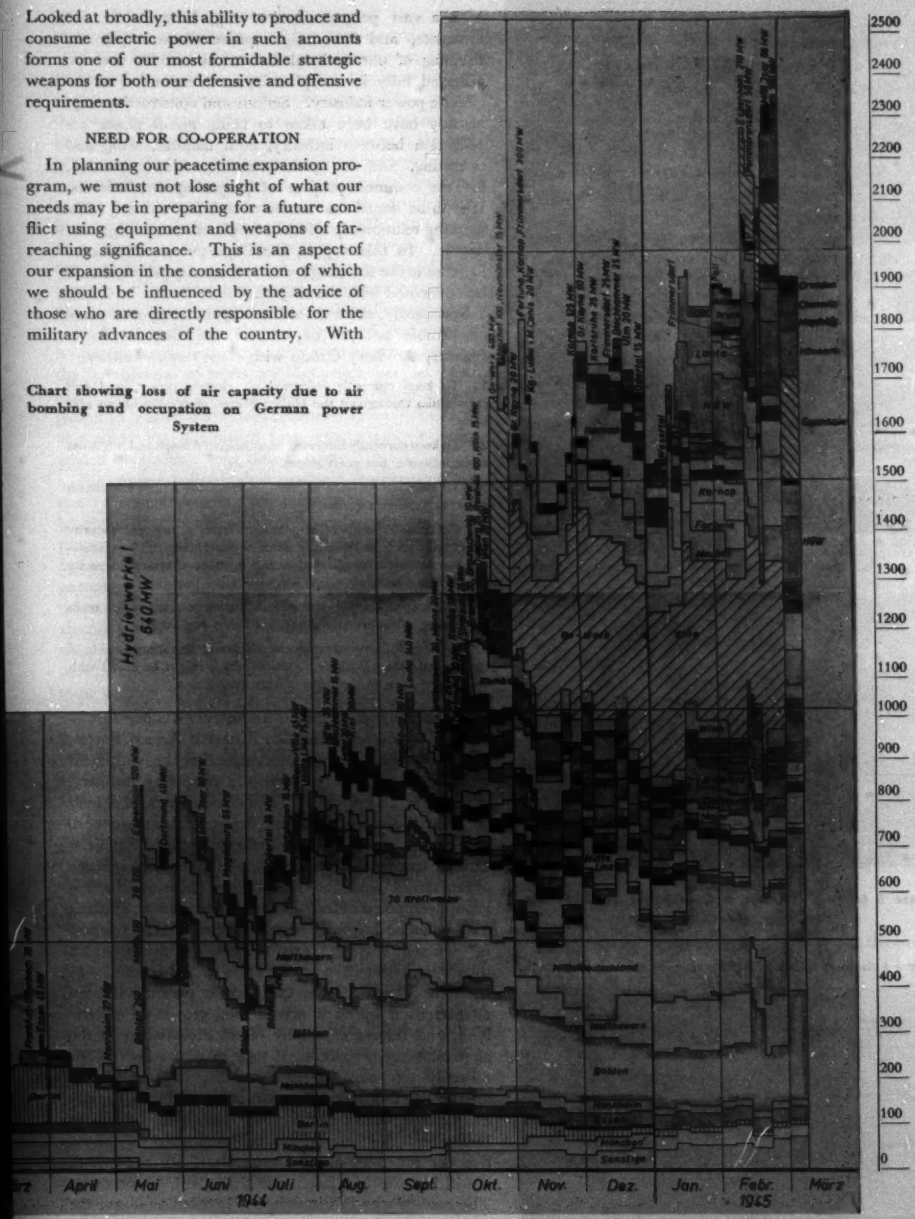



**Chart showing loss of air capacity due to air bombing and occupation on German power System**

Figure 1. Enemy demolition, Geertruidenberg power plant, Netherlands

Figure 2. Floating power plant, Langerbrugge, Belgium

Figure 3 (above). Damage to Caen power plant, France, caused by artillery operations

Figure 4 (below). Camouflaged switching station, Hoheneck, Germany

such a vast program under way, it would be unfortunate, and later might prove disastrous, if the thinking of our national defense authorities was not reflected fully in the planning and expansion of the electric power industry. Serious and constructive steps already have been taken to bring about closer cooperation between industry, both manufacturing and operating, and the government agencies concerned, for the common purpose of preparing our defenses. It is to be hoped that measures to bring about a fuller working relationship will be stimulated to a still greater degree. In this respect, the Department of National Defense is the logical government agency which should be concerned with the subject.

Specifically, there should be appointed by and made answerable to that department, an Electric Power Industry Advisory Group with these responsibilities:

1. To keep currently informed on electric power load and capabilities throughout the United States, preferably on an area basis.

2. To keep currently informed on anticipated loads and additions to capacity for five years ahead.

3. To keep informed as to possible new loads which are known only to the Armed Forces.

4. To consider matters of planning from a national security standpoint such as types and sizes of generating stations, transmission and switching facilities, and amount of reserve capacity needed for reasonable reliability.

5. To keep informed on manufacturing capacity for main generating, transformation, and switching equipment.

6. To keep informed on the electric power situation outside of the United States in those countries which might be allied with or opposed to us in the event of future hostilities.

Membership on such an Industry Advisory Group should include representation from the Armed Forces, the federal and state regulatory agencies, the equipment manufacturing industry, and the operating industry, both public and private. The personnel named should be from the top engineering executive levels of both government and industry so the adoption of policies can be carried out effectively within their respective organizations and the industry in general. Such a group, composed of individuals of independent thinking and action and working together for a common purpose of national defense, could accomplish much which otherwise might have no direction or guidance.

In the United States, the postwar period has been characterized by an unprecedented growth in electric load, and reserve capability of electric systems in the aggregate has been reduced to a margin which is admittedly too narrow. Every utility organization is attempting to re-establish normal margins as rapidly as possible. During the 1947 peak-load period in December, this reserve margin amounted to about five per cent. As the power projects are completed, it will increase at a faster rate than the load increases. The reasons why this margin has become small are the

result of two main causes which are well understood by those who are close to what has been happening.

In the first place, it has been impossible to install additional generating capacity sufficiently early in the postwar period because of direct war production during the war itself and delays resulting from strikes and shortages of materials. It was not until close to the end of the war that manufacturing facilities, materials, and manpower, again could be directed toward building heavy power equipment for peacetime installations. Because of the long time required for the building of such equipment, the first postwar years, 1946–47, saw the installation of a relatively small amount of new capacity. The situation was complicated by strikes and the inadequate supply of materials and manpower.

In the second place, the unprecedented load growth itself has placed demands on the utility systems beyond the predictions of even well-informed people. The load growth has occurred, however, and there is good reason to believe that it will continue, although perhaps at a somewhat diminished rate without serious or extended breaks for a long time to come.

The author believes that practical requirements for reserve capability of large interconnected systems should be about 15 per cent of load demands to take care of proper operating reserves and maintenance schedules. Isolated systems should have a higher figure. This percentage of reserve should be of sufficient amount to meet all peacetime requirements and, in addition, should provide a margin of reserve required to meet defense requirements. The amount of the defense part of the reserve margin will depend upon needs and must be discussed with military people conversant with the subject. In contrast to the thinking of some, it is believed that this "defense reserve," so to speak, whether in generating, transformation, switching, or transmission facilities should be built right into the systems and form an integral part of them. It should be recognized that this is done purposely and with the full knowledge and concurrence of all interested parties—the consumers, the municipal and state regulatory authorities, and the federal agencies involved. The economic considerations require careful study and examination. Wartime experience in areas overseas has proved this to be the correct approach to the problem rather than a superimposing of some scheme of standby facilities owned by government and located around the country. This, however, does not preclude such standby facilities as the Armed Forces require such as the floating power plants. In war-torn areas abroad, the restoration of electric power service other than on a bare minimum basis had to be accomplished by restoring the existing integrated facilities which normally were a part of the system. This is the practical way to do it.

From a national defense standpoint, there should be additional ties between some systems already inter-

Figure 5. Damage to Gennevilliers power plant, Paris, France from equipment failure

Figure 6 (above). Underground power plant, Mannheim, Germany

Figure 7 (below). Stripped turbine room, Berlin, Germany

connected and ties between others not yet interconnected. Such interconnections generally could not be justified during peacetime because of the cost involved—the operating economies would not be sufficient to take care of the fixed and operating expenses. However, these are interconnections which ought to be made in peacetime and not be done, as was necessary during the last war, at a time when materials and manpower were needed vitally for other direct war production requirements. It is neither fair to, nor in the best interests of, the national economy that such interconnections, if made, be held open during peacetime because of provisions of law which now discourage such ties. It is to be hoped that the Congress will modify the law so as to encourage such national defense interconnections during peacetime between utility systems without incurring dual regulation by both federal and state regulatory bodies in matters which are local in character and properly subject to local regulations.

The sources of energy for electric power generation undoubtedly will be, for a long time to come, from those with which we are most familiar, namely, heat or thermal energy derived from the burning of gaseous, liquid, or solid fuels, and from the hydraulic energy of falling water. We should not delay our planning for new construction in anticipation of the early development or influence of nuclear energy. Consequently, our planning and construction should go forward along conventional and presently known means of power generation.

It is the belief of the author that wherever possible generating sources should be decentralized within reasonable limits and large concentrations of generation should be avoided. This is not always possible and good judgment and economic considerations must prevail in taking a "calculated risk" in such instances. Underground power plants are not the answer because even they can be damaged from bomb effects, and generally are impractical. This type of plant was tried in Germany and the contribution to continuity of power supply was small, if any. Sources of power generation should not be located close to other industrial plants, if it can be avoided, because wartime experience has proved that power facilities, even though not objects of attack, may be damaged heavily because of the wider area affected than just the target itself. A striking example of this was the extensive damage to the Goldenberg power plant, the largest in Germany, resulting from an air attack on a nearby chemical plant.

The damage resulting from sabotage is a matter which must not be overlooked. In the future it may be far more important than in the past. Sabotage was used extensively by the underground elements in Europe in frustrating war production for Germany in invaded territory. The electric power systems and the various agencies of government must be alert and not lose sight of this problem if trouble is to be avoided.

So that the full electric power resources of the country can be utilized, if there be need to mobilize industry as was done during the last war, there should be a continuing plan of bringing together qualified personnel from both the industry itself and from the agencies of government concerned. Only by such means can we have available the type and kind of people and experience able to work together effectively in the national interest. Such an organization and staff existed during the last war and well could serve as a model for future action. It was far superior to that which existed in Germany for the same purpose.

Fortunately, our power facilities suffered no damage from enemy action during the past war. The hum of our generating units was not stilled by sabotage, planned demolition, bombing, or other operational destruction which comes with active warfare; nor was there disruption of communication and transportation, or depletion of materials and supplies for operation and maintenance, or lack of necessary manpower, or the general civil disorganization which results wherever and whenever destruction is widespread. But can it be said that we always shall be free from these destructive forces? Or that we shall have time to prepare? And that the oceans are our first line of defense? Today the United States has become a nation whose borders extend far out beyond its natural land areas. Our military and civilian forces are in occupied areas in Europe and Asia; our efforts in promoting effective peace for hundreds of millions of people are being carried on thousands of miles from home. Whether we like it or not, we are concerned with almost the entire world.

In conclusion, let us summarize these thoughts and try to present ways and means of bringing about constructive results which will help to maintain our nation's industrial capacity in time of war:

1. An adequate supply of electric power is essential to both a healthy peacetime economy and to the preparation and carrying out of a national defense program.

2. During peacetime, there should be drawn an effective coordinated plan which would provide guidance in the expansion of the electric power industry in relation to national defense.

3. The experience of the last war should be drawn upon heavily in planning moves to be made in the event of widespread destruction resulting from future hostilities.

4. There should be formed at an early date an Electric Power Industry Advisory Group by the Department of National Defense to be concerned with subjects earlier outlined. This action is vitally important.

5. The participation of the electric power industry during peacetime in matters involving our national defense certainly would lead to the fulfillment of constructive military objectives. It was one of the most patriotic and co-operative industries in the last war.

6. The maintenance of a position of national industrial strength is, in the author's opinion, the best assurance of the prolongation of world peace. Investment in the industrial system which is recognized as typical of the United States is the most hopeful means of defending the nation's traditional way of life.

# Detection and Measurement of Nuclear Radiation

G. WESLEY DUNLAP
MEMBER AIEE

**Methods of measuring nuclear radiation have been described meticulously in technical literature as they were developed. This summation should provide a good basis for the understanding of current and future literature describing specific instruments, newer refinements of the measurement technique, and nucleonics research. This is the fourth in a series of articles developed by the AIEE nucleonics committee.**

AN important part of any general discussion on a technical subject is the question of measurements. The inclusion in this series of a survey of the methods used in the detection and measurement of the radiations that invariably are associated with nuclear reactions is both necessary and appropriate.

Although radiations frequently will be found grouped according to origin, charge, mass, energy, penetration, or ionization ability, the general problem of radiation detection and measurement requires only a simple listing of the various types with their pertinent characteristics (as in Table I).

By far the greatest bulk of measurements will be concerned with X rays, gamma rays, alpha rays (particles), beta rays (particles), and neutrons. The characteristics of all these long since have been determined and have been summarized and discussed in other articles of this series.[1,2]

## QUANTITIES TO BE MEASURED

Depending on the particular problem at hand, the determination of one or more of the following may be important:

1. Presence of radiation. This may include identification of the type, for example, alpha, beta, gamma, or neutrons.

2. Intensity of radiation. This is a measurement of rate and is determined in terms of particles per unit area per unit time (counts per minute or per second)* or in units based on ionizing effectiveness (roentgens per minute for high intensities or milliroentgens per hour for low intensities).†

3. Quantity of radiation. This refers to the integrated amount of radiation over a given period of time and usually is expressed in total counts or in roentgens.

4. Energy of radiation. This refers to the kinetic energy of the radiation particles or quanta and is expressed in electron volts or more commonly in million electron volts. The determination requires that the types of radiation be known.

The need for such measurements arises in connection with a number of activities in the nucleonics field. These are more or less obvious and only need be summarized here. First, and of primary importance, is the protection of personnel from the physiological effects of radiation. Next is the matter of research on nuclear reactions including the work with high energy accelerators and the cosmic ray studies. Then the use of radioactive isotopes as tracers in a wide variety of problems in the fields of medicine, biology, and industry is an activity of great interest and growing importance. Finally, there are the multitude of problems connected with the development and operation of chain-reaction piles.

## METHODS

All of the known methods of radiation measurement depend on the ionizing ability of the radiation; and where this is not present as in the case of neutrons, detection is only possible by virtue of secondary effects in which ionizing particles are produced. A review of the basic methods which are available for the detection and measurement of radiations will illustrate this fact.

*Fluorescence.* The discovery of X rays was made through the observation of the fluorescence that they produced in barium platino-cyanide crystals. Many materials show fluorescence under radiation, and the utilization of this phenomenon in the fluoroscope for radiological work is, of course, well known. In addition, Sir William Crookes utilized fluorescence to count nuclear radiations with the development in 1903 of the spinthariscope.

In this device, shown diagrammatically in Figure 1, particles such as alpha particles or high speed protons striking the zinc sulphide screen produce tiny flashes of light which may be seen through a microscope. Such a device is highly sensitive in that individual particles may be observed, and it is semiquantitative

**G. Wesley Dunlap** is with the general engineering and consulting laboratory of the General Electric Company, Schenectady, N. Y.

* "Counts" or "counts per minute" refer to the impulses observed with a "counter." When corrected for geometry and efficiency, counts per minute indicate the rate of emission of particles and hence the rate of atomic disintegrations in a radioactive substance. The unit for this is the Curie which is accepted as $3.7 \times 10^{10}$ disintegrations per second (the rate of emission of alpha particles from one gram of radium).

† The roentgen $r$ is defined as the quantity of X or gamma radiation that will produce in one cubic centimeter of air at standard temperature and pressure, ionization amounting to one electrostatic unit of charge of either sign. This is $2.083 \times 10^9$ ion pairs per cubic centimeter standard air or $1.61 \times 10^{12}$ pairs per gram of air.

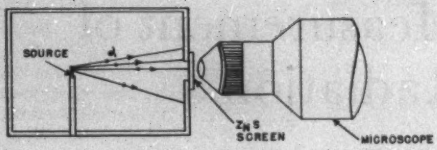



**Figure 1. Spinthariscope**

for low intensities. The spinthariscope was used widely in the early radiation experiments, and in particular it was the instrument for Rutherford's famous "proton experiment" in which the transmutation of one element into another first was demonstrated. It is still in use, but for the large bulk of radiation measurements it has been supplanted by the more convenient electronic techniques.

In passing, it is perhaps well to note that fluorescence often is accompanied by a change in color of the material, and early measurements of X-ray dosage were produced, by means of such color changes, in barium platino-cyanide pastilles.

*Photographic Emulsions.* Radiation from radioactive substances first was detected by the blackening of a photographic emulsion and this remains today one method of detection and semiquantitative measurement. The film used in taking an X-ray photograph or radiograph records relative intensities of radiation over a given area, and for more specific measurements the actual density of a film area can be used with proper calibration to indicate quantity of radiation.

A measurable density is produced on a film by the so-called tolerance dose for X rays, that is, 0.1 roentgen per day. For this reason small pieces of film serve as convenient devices for checking the radiation exposure of personnel.

In addition, it is sometimes possible, with the aid of a microscope, to observe in a developed emulsion the actual tracks of individual particles. This technique, while of limited usefulness in the general measurement field, is of considerable interest in nuclear research, and special emulsions have been developed to produce better tracks.

*The Electroscope.* As indicated, it was discovered very early that gases would be ionized by either primary or secondary effects of radiation, and most of the commonly used instruments utilize this particular characteristic. The simplest such instrument is the electroscope, and Figure 2 shows the familiar "gold-leaf" electroscope which is used in every physics laboratory to demonstrate the nature of electric charge.

The operation of this device as a radiation instrument is as follows. With a charge of either polarity on the electrode the leaf is deflected away from the support by the repulsion of like charges, and the angle of deflection is a measure of the amount of charge on the system. Then in the presence of radiation the air in the electroscope becomes ionized and hence conducting so that the charge leaks off and the leaf falls. The rate of decay of charge as indicated by the rate of fall of the leaf is then a measure of the intensity of radiation.

In spite of its simplicity the electroscope had been of tremendous importance in nuclear research. High sensitivity and precision may be obtained by special attention to design details, and two instruments that have been so designed are the string electroscope of Milliken and Bowen[3] and the Lauritsen electroscope.[4] Both of these utilize gold-coated quartz fibers as deflecting elements and in each instance high sensitivity is achieved with a compact and rugged instrument.

*The Ionization Chamber.* This is a broad classification that embraces a wide variety of actual instruments ranging from simple pocket chambers to complicated precision instruments capable of covering many decades of sensitivity. However, all devices to be discussed under this heading have in common a detecting element consisting of a semi- or totally-enclosed chamber inside of which the ionization produced by the radiation to be measured takes place.

As shown in Figure 3, this ionization chamber is much like a capacitor. It has two or more electrodes separated by a dielectric of air or other suitable gas. Its distinguishing feature is that it is so proportioned and the voltage is so adjusted that all ions produced in its volume are collected before appreciable recombination can occur. However, the gradients are kept low enough so that secondary ionization (additional ionization produced by collisions of the original ions with neutral molecules) does not take place.

As an integrating instrument to measure total amount of radiation over a given period of time, the chamber

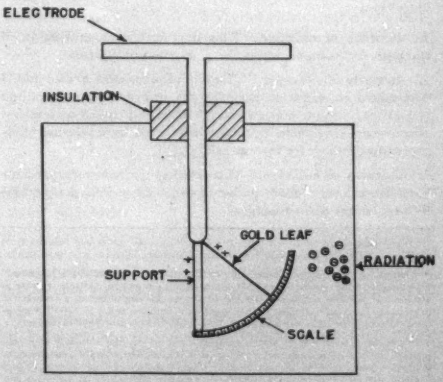
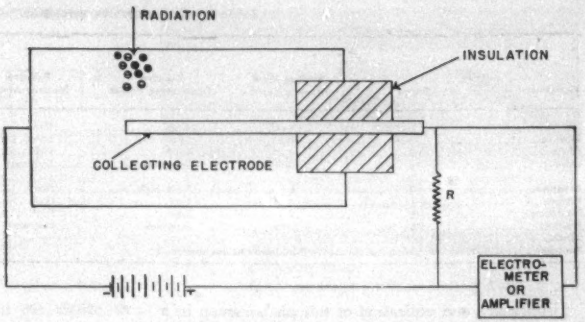



**Figure 2. Electroscope**

**Figure 3. Ionization chamber**




is given an initial charge and after exposure its loss of voltage is determined. This usually is done by means of an electronic voltmeter or an electrometer as the amount of charge involved is extremely small. The change in voltage is equal to $1.6 \times 10^{-7} n/c$ where $n$ is the number of electrons arriving at the positive electrode and $c$ is the capacitance of the electrode in micromicrofarads.

Examples of this type of application are the "*r* thimbles" for measurement of X-ray dosage and the pocket ionization chambers called minometer pencilsor personnel dosimeters which are used to monitor personnel dosage for health protection. Both normally are used with auxiliary instruments specifically designed to supply the initial charge and measure the total exposure.

If now a constant potential is applied to the chamber as indicated in Figure 3, ions produced by radiation are collected because of the electric field in the chamber and the resultant current through the high resistance $R$ produces a potential across $R$ which can be measured. Such a measurement—which may be performed with an electrometer, a special amplifier, or an electrometer tube and galvanometer—is a measure of rate of ionization and hence of radiation intensity. Such a system also may be designed to detect and hence count individual ionizing events such as the passage of a single alpha or beta particle or cosmic ray.

It should be noted that many precautions in the design and operation of these devices are necessary because of the extremely small quantities involved. For example, the gamma rays from one milligram of radium will produce in an ionization chamber at a distance of ten inches a current of one micromicroampere per liter of chamber volume. This intensity of radiation is about tolerance level.

In spite of such requirements, progress in the development of this type of instrument has been such that there are available compact, portable, "survey" instruments which include battery-operated chambers and amplifiers capable of measuring radiation intensities somewhat lower than indicated in the foregoing. Greater sensitivity and in particular greater stability is obtained with more elaborate equipment.

*Counters.* This heading is also broad in that it is taken to cover basic elements which may be combined in many ways to produce an almost endless variety of instruments, each adapted to a specific type of measurement. Here again the common denominator is the detecting element, in this instance the counter tube. For the purposes of this discussion, a counter tube will be considered as one in which "gas amplification" takes place or, in other words, one in which the original ionization produced by the radiation is augmented by secondary ionization.

This may be explained in the following manner. Suppose a chamber similar to that indicated in Figure 3 has concentric cylindrical electrodes. If then the radius of the central conductor is reduced greatly, say to a fine wire, the electric gradient near it will be high so that electrons formed in the initial ionization event will be accelerated to sufficient velocities to produce secondary ionization in the gas of the tube. Thus, many more ions than originally were produced by the radiation are available for collection and self-amplification or gas amplification is obtained.

Victoreen Instrument Company

**Figure 4. Pocket ionization chamber for personnel monitoring with Minometer for charging and reading**

**Table I. Radiation Characteristics**

| Radiation | Charge | Approx Mass (Atomic Units) | Relative Penetrating Power | Relative Ionizing Ability | Max Kinetic Energy, Mev: From Nuclear Emission | Max Kinetic Energy, Mev: From Existing Acceleration |
|---|---|---|---|---|---|---|
| X rays | 0 | 0 | High | Low | | 100 |
| Gamma | 0 | 0 | High | Low | About 3 | |
| Alpha | +2 | 4 | Low | High | About 9 | 400 |
| Beta | −1 | 1/1840 | Intermed | Intermed | About 11 (most less than 3) | 100 |
| Neutrons | 0 | 1 | Very high | None | | 200 |
| Protons | +1 | 1 | Low | High | | 100 |
| Deuterons | +1 | 2 | Low | High | | 200 |
| Positron | +1 | 1/1840 | Intermed | Intermed | | |
| Meson | +1 or −1 | 0.1 | | | | |
| Neutrino | 0 | (Postulated but not observed.) | | | | |

Historically, the utilization of this phenomenon in a radiation instrument dates from 1908 when Rutherford and Geiger used the discharge from a point electrode to count alpha particles. Subsequently the pressure in the chamber was reduced and the point replaced by a fine wire to improve the performance. Additional improvements were the result of the work of Geiger and Mueller, and such tubes are known as Geiger counters, Geiger-Mueller counters, or simply G-M tubes.

Counter tubes are made in a variety of forms to fit particular needs, but the most common type is the cylindrical, concentric construction illustrated in Figure 6. Dimensions vary over a wide range depending on the application, and very thin walls or windows may be provided to admit the less penetrating radiations. Windows may be thin sections of a glass wall two or three mils thick or equally thin mica sheets cemented or clamped on the end of a tube. Even thinner windows of plastic are used with some chambers where mechanical strength is not necessary. Window thickness is specified in milligrams per square centimeter and one to five is a "thin" window. Various gases at various pressures may be used, but in any case care must be taken to assure clean surfaces and that the tubes are evacuated before the gas is introduced.

**Figure 5. Battery-operated portable survey instrument of the ionization chamber type**

*Left-hand view shows partly open metal and plastic filters for excluding alphas and betas respectively*

The operation of a Geiger counter is as follows. Ions and electrons produced in the gas by incident radiation are accelerated by the electric field; and as indicated, the electrons, particularly in the high gradient near the central wire, reach velocities high enough to ionize the gas molecules with which they collide. The secondary electrons in turn are accelerated and produce more secondaries so that an avalanche is started and the discharge rapidly spreads throughout the tube. Thus the tube behaves much as a thyratron which has been triggered and a pulse of current flows through the resistance $R$. The resultant voltage drop in $R$ reduces the tube potential so that the discharge goes out and the tube is restored to its original condition to be ready for another count. This quenching action may be supplemented by more elaborate circuit arrangements (electronic quenching) or by the introduction of a polyatomic gas (self-quenching).

The pulses produced by a typical Geiger-Mueller counter will be of the order of volts, and therefore can be detected easily and "counted" with modern electronic circuits. Because the pulse size is a function of the resistance $R$, the applied voltage, and the counter construction (all of which are constant for a given instrument), the pulses are all of the same size regardless of the number of ions originally produced by the radiation.

If a counter tube is connected to an appropriate electronic circuit and exposed to a source of constant radiation, a curve similar to that shown in Figure 8 may be determined. This "characteristic curve" represents the counts per minute observed as a function of the voltage applied to the tube. It can be observed that as the voltage is raised, the counting rate reaches a practically constant value between $B$ and $C$. This plateau is known as the "Geiger" region and a Geiger-Mueller

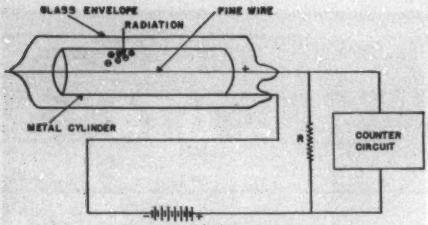



**Figure 6. Geiger-Mueller tube**

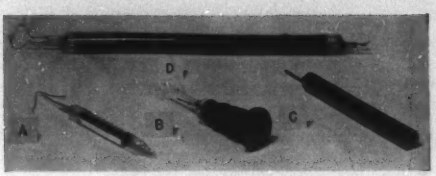



**Figure 7. Counter tubes**

*A—Thin-wall Geiger-Mueller counter*
*B—End window counter tube (thin window)*
*C—Neutron counter*
*D—Geiger-Mueller counter for gamma or X rays*

counter is operated in this region. At any particular voltage within this range all ionizing events taking place within the tube will produce pulses of equal size. All such events will be registered as single counts provided their spacing in time is greater than the recovery time of the tube.

The voltage region above *C* is of no practical importance because the tube soon goes into continuous discharge as the voltage is raised.

In the voltage region below *B*, it is no longer true that for a given voltage all ionizing events taking place within the counter tube produce pulses of equal size because the discharge does not spread through the entire tube. Those particles which produce a larger number of ions per unit length of path will cause larger pulses. Because it is true that the pulse size is proportional to the ionizing ability of the particle, this is known as the proportional region and a counter so operated is known as a proportional counter. It should be pointed out that as the voltage approaches the Geiger region (point *B*), pulse sizes are not strictly proportional to ionizing ability, and hence there is a region of "limited proportionality."

The proportional counter is used when it is desirable to count only particles of energies greater than a selected value, or to count one type of particle and to ignore another. A common practice is to arrange the counter and circuit to count only alpha particles in the presence of betas and gammas. This is done by the introduction of a discriminating circuit or pulse height selector which passes only pulses of amplitude greater than a predetermined value; or the particles may be distinguished by observation of the pulse size on an oscilloscope screen.

The counter is an extremely sensitive instrument in that it will operate on a single ionizing event such as the passage of a single beta particle. However there is present a "background" of a few counts per minute which sets a lower limit to practical counting rates. With care in construction and shielding this may be reduced but never completely eliminated. At the upper end the limit is in the order of $10^5$ counts per minute. To use the example given for ionization chambers as a basis for comparison, the gamma rays from one milligram of radium placed 10 inches from a common type of Geiger counter would produce a rate of roughly 40,000 counts per minute.

Counter tubes are used in conjunction with a wide variety of circuits. In the simplest form the pulses from the counter simply are amplified enough to energize a

**Table II. Guide to Applications of Measurement Methods**

| Method | Radiation Detected* | Approx Range | Common Uses |
|---|---|---|---|
| Fluorescence | Alpha, beta, X rays | Individual particles, visible indication with order of 1 r/min | Research, demonstration, fluoroscopy |
| Photographic emulsion | Gamma, X rays, alpha, beta, neutrons | Approx 0.01 to 50 or 100 *r*, individual particles | Health protection, research |
| Electroscope | Alpha, beta, gamma, X rays | Few particles or few milli *r* to 100 times this quantity (depends on insulation resistance) | Research, demonstration, health protection |
| Ionization chamber | Alpha, beta, gamma, X rays, neutrons | Depends on design, single particles to present maximum intensities but not in single instrument, practical range of six decades in single instrument | Health monitoring, research, control, analysis |
| G-M counters | Alpha, beta, neutrons, X rays, gamma | Single particles to several thousand per second, 0 to a small fraction of an *r*/min | Health monitoring, research, control, analysis |
| Proportional counters | Alpha, beta, neutrons | Single particles to several thousand per second (faster than G-M counter) | Health monitoring, research, control, analysis |
| Electron multiplier | Alpha, beta, gamma, X rays, neutrons | Probably greater range than G-M counter | In development, presumably same as G-M counter |
| Crystal counter | Alpha, beta, gamma (neutrons not yet reported) | Probably greater than G-M counter | In development, presumably same as G-M counter |
| Cloud chamber | Alpha, beta, neutrons | Single or very few particles | Research |

*Not all detector elements will detect all types of radiation (see text).

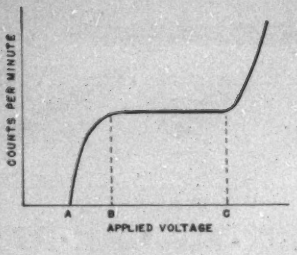



**Figure 8. Geiger-Mueller counter characteristic**

loud-speaker, glow lamp, or oscilloscope to give an audible or visual indication of each count. This is adequate for detection of radiation or semiquantitative evaluation of low counting rates. Then there is the mechanical register or counter which may be connected to the amplifier to record the counts directly. This, of course, is limited to low rates, around 1,000 per minute, so for higher rates electronic scaling circuits are used.

With such arrangements the total number of counts in a given interval of time is obtained to give the integrated quantity of radiation or, by simple arithmetic, the rate or intensity of the radiation. In addition, however, circuits may be used which will indicate the counting rate on a meter. This is the "counting-rate meter" frequently used as a survey instrument.

*The Electron Multiplier.* Another device, and one of more recent origin, which may be used for counting is the electron multiplier. Its operation depends on the fact that for some substances an incident electron may produce more than one secondary electron. With the proper arrangement of electrodes and potentials (Figure 11) so that secondaries produced at a surface are directed to a second electrode and so on, the effect may be cascaded and an over-all amplification obtained.

Tracerlab, Inc.

**Figure 9. Automatic counting equipment showing lead shield in which counter and sample are located to obtain low background**

**Figure 10. Scaler for use with counters**

Such a tube commonly is used as a photoelectric tube and is known as a multiplier photoelectric tube or photoelectric multiplier. For the measurement of radiation, a photoelectric multiplier may be used in conjunction with a phosphor which will convert the radiation into visible light by fluorescence. In this instance it becomes a sort of electronic spinthariscope. In addition, however, the electron multiplier may be designed so that the radiation produces secondary electrons at the cathode surface by direct bombardment.

Perhaps the chief advantage of this device as a counter is its high speed. As the action is not limited by the necessity for quenching as in a Geiger-Mueller tube, the resolution time or time between successive counts may be extremely small. In addition, the "built-in" amplification of a multiplier tube is of real practical value.

*The Crystal Counter.* The newest device in this list of radiation detection and measuring devices is the crystal counter. Its action depends on a phenomenon which is apparently similar to the photoelectric conduction which is observed in many crystals. This is the displacement within the crystal, under the influence of an applied electric field, of electrons freed by the photoelectric effect. Presumably electrons similarly may be freed by the radiations under discussion here, and it has been demonstrated that counting may be achieved under certain conditions.

Such a demonstration was reported in 1945 by Van Heerden[5] who used silver chloride crystals at liquid air temperature. Other investigators have announced within the last year successful results from diamonds. An important advantage of the crystal counter is the very small size of the detecting element. While the associated electronic circuits are similar to those required for Geiger-Mueller tubes, the small volume of the crystal should prove very useful in many applications.

*The Cloud Chamber.* The devices already described provide a great deal of information about radiation.

Quantity and intensity of radiation may be measured. Individual particles may be counted and it is possible to distinguish between the various types of radiation. In addition, it is possible, by means of absorbers or filters, to find out something about energy levels. However, these are all statistical results, and it would be very informative if a single particle could be observed and its particular characteristics determined.

This desirable result actually is achieved with the cloud chamber or Wilson cloud chamber as it frequently is called in honor of C. T. R. Wilson who introduced it in 1911. The operation of this device depends on the fact that in a supersaturated vapor condensation will take place preferentially on charged particles. This

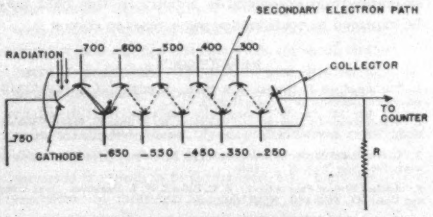



**Figure 11. Electron multiplier**

then permits the visual observation of the path of a radiation particle by virtue of the droplets of liquid condensed on the ions left in its wake.

The physical means for realizing this effect are illustrated diagrammatically in Figure 12. In a transparent chamber, air or some other suitable gas saturated with water vapor is compressed by raising the piston to a predetermined position. Time must be allowed for the heat of compression to be dissipated; and then if the gas is allowed to expand suddenly by dropping the piston, uniform volumetric cooling occurs and the vapor becomes supersaturated. If at this time a particle enters the chamber, moisture droplets will condense on the ions formed. Illumination by a bright light will render the "track" easily visible, or a photograph may be taken to serve as a permanent record of the event.

If, in addition, a magnetic field is provided in the chamber the tracks will be curved; and as the radius of curvature depends on the mass and energy of a particle, further information is obtained.

Figure 13 shows a cloud chamber photograph. As there is almost no chance of the desired tracks being in a single plane, two or three views are taken from different angles by means of mirrors to permit analysis. In the two views reproduced here there is seen a "star" or atomic disintegration against a background of electron tracks.

Here several particles have been ejected from a gas atom's nucleus under the influence of 100-million-elec-

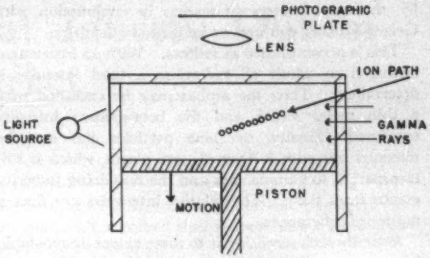



**Figure 12. Cloud chamber**

tron-volt X rays from a betatron. The heavy track extending toward the bottom of the picture is identified as an alpha particle while the two upward tracks are protons. The short stub of a track barely discernible at the origin is the residual nucleus.

From such photographs measurements can be made to determine rather completely the characteristics of a particle. These include the following:

1. Direction—for conservation of momentum calculations.
2. Range—for mass and energy determinations.
3. Density of ionization (density of track)—for mass and energy determination.
4. Radius of curvature—for mass, energy, and charge determination.

*Techniques for Distinguishing Radiations.* While cloud chamber measurements permit identification of individual particles, various techniques are used with some of the other methods. The proportional counter, of course, has been mentioned as capable of discriminating between alpha particles and a background of betas and gammas; and a similar discrimination may be effected

Obtained by G. C. Baldwin and G. S. Klaiber of the General Electric Research Laboratory, Schenectady, N. Y.

**Figure 13. Cloud chamber photograph (with stereo view)**

by the use of filters or screens in conjunction with Geiger-Mueller counters or ionization chambers.

This is accomplished as follows. With an instrument arranged to admit all radiations a total intensity is determined. Then the alphas may be excluded with a thin metal screen and the beta-gamma intensity measured. Finally, the beta particles also may be screened out with a filter of, say, plastic which is still transparent to gamma rays and the remaining intensity results from these. The relative intensities are then a matter of differences.

Actually such screening is to some extent unavoidable because even distance in air provides this effect and special detection elements such as open chambers or thin window counters are required to admit alpha and beta particles. It may be said that these distinguishing measurements are possible, but there is no single instrument with a "selector switch" for alphas *or* betas *or* gammas.

For the detection of neutrons it was pointed out that indirect effects are utilized and this requires that some element which is a good neutron absorber like boron be present. The measuring volume may be filled with boron trifluoride ($BF_3$) gas, for example, or the chamber walls may be coated with boron. To distinguish between neutrons and a background of other radiations, a differential method may be used wherein the output of a similar detector without the neutron sensitive substance is used to balance out the background component of the neutron detector.

In concluding this brief survey of radiation measurement methods, a few very general remarks may be appropriate. Obviously, we barely have "scratched the surface." It would be impossible in a reasonable space to describe all of the modifications and specific applications of the methods listed here. However, an outline has been given of the various paths which have been and are being followed in the development of the art.

Within the scope of this discussion Table II gives a rough guide to the usefulness of the various methods. More detailed descriptions in many instances may be found in the references[8–10] or in the current technical literature.

Finally, it should be said that while a great deal of effort is going into instrument development and much progress is being realized, there is still much work to be done. There is a need for more ruggedness, reliability, and simplicity in existing instruments; and the matter of standardization is just coming under consideration; so considerable activity in this field may be expected to continue for some years to come.

REFERENCES


1. The Atom and Its Nucleus, **J. J. Smith.** *ELECTRICAL ENGINEERING*, volume 66, December 1947, pages 1165–75.

2. The Nucleus—Its Structure and Reactions, **W. E. Shoupp, Hugh Odishaw.** *ELECTRICAL ENGINEERING*, volume 67, February 1948, pages 125–34.

3. Classicals and Modern Physics (book), **H. E. White.** D. Van Nostrand Company, Inc., New York, N. Y., 1940.

4. Applied Nuclear Physics (book), **E. C. Pollard, W. L. Davidson.** John Wiley and Sons, Inc., New York, N. Y., 1942.

5. The Crystal Counter (book), **P. J. Van Heerden.** N. V. Noord-Hollandsche Uitgevers Maatschappij, Amsterdam, Netherlands, 1945.

6. Radioactivity and Nuclear Physics (book), **J. M. Cork.** Edwards Brothers, Inc., Ann Arbor, Mich., 1946.

7. The "Particles" of Modern Physics (book), **J. D. Stranathan.** The Blakiston Company, Philadelphia, Pa., 1945.

8. Introduction to Modern Physics (book), **F. K. Richtmyer, E. H. Kennard.** McGraw-Hill Book Company, Inc., New York, N. Y., 1942.

9. Introduction to Atomic Physics (book), **Henry Semat.** Rinehart and Company, Inc., New York, N. Y., 1946.

10. Electron and Nuclear Counters (book), **S. A. Korff.** D. Van Nostrand Company, Inc., New York, N. Y., 1946.


## Electrical Diamond Properties

Two interesting electrical properties of diamonds have been reported recently—sensitivity to gamma radiation and the ability to amplify electric currents.

Radioactivity studies conducted at the National Bureau of Standards have shown that diamonds are highly sensitive to gamma rays amd may be used to detect this radiation in the same way as a Geiger-Mueller counter. It has been found that a diamond placed in a strong electric field initiates sharp electrical pulses when gamma radiation is absorbed. The diamond is clamped between two brass electrodes maintained at a difference of potential of about 1,000 volts. When a source of gamma radiation is brought within the range of the diamond, there occurs at the electrodes pulses of current which after amplification may be detected and counted on any suitable indicating device. The number of counts per unit time is a measure of radiation intensity.

During experiments at the Bell Telephone Laboratories small diamond chips bombarded with a beam of electrons have yielded currents as much as 500 times the original beam current. The diamond crystals used are about a quarter of an inch square and approximately 0.002 inch thick, and the flat surfaces are coated with gold to afford electrical connections. An alternating voltage is applied to the chip and it is bombarded with successive pulses of electrons of about one microsecond duration. Energies of about 15,000 electron volts were used, and in some experiments beam currents have been amplified as much as 500 times by this technique. One important feature of the new technique is that the induced currents are produced in very short times—in the order of less than one-tenth of a microsecond, it is believed.

# How to Price Political Liberty Out of the Market

R. W. KING
MEMBER AIEE

**Modern science and technological "know-how" constitute a team, the extraordinary capacity of which was demonstrated in World War II. Will this team continue to be the servant of democracy, or may it become a Frankenstein capable of forcing the American people into political subservience? A well-known observer offers provocative criticism of the current scene and some of the current proposals. He points out that as a democratic state becomes more highly industrialized, the eternal vigilance which is its price of liberty must deploy itself over an ever-widening front to meet new encroachments if freedom is to be preserved. Can we continue to counter the threats of our industrialism? The author wishes to emphasize that these are his own personal views.**

SCIENTISTS and engineers as a group may be likened to the thyroid gland. They constitute a small but extremely important organ in the body politic, and the stream of new knowledge which they pour forth, when it reaches the channels of trade, has a vital influence upon the living standards of a state. An active secretion denotes a progressive and forward-looking society—perhaps a trifle on the restless side. A meager secretion marks a lethargic, unprogressive people. And as for an overactive science gland, it is perhaps a mild form of heresy to suggest that there can be such in any social organism.

But whether heretical or not, it is my present purpose to raise the doubt and then to inquire whether in the American economy it presents a potential source of difficulty. This, it will develop, is an invitation to engineers to sit in judgment upon some of their own acts.

The reason for setting forth on this inquiry springs chiefly from a well-known phenomenon. If mankind were like pigeons in flight, taking its opinions instantly from some competent leader, as a flock will rise or wheel almost as a single bird, the following remonstrance scarcely would be called for. But any large social group enters into its mass opinions so slowly that long before flood tide is reached, it is proper that some forces begin to pull in a reverse direction. Electrical engineers, in particular, will recollect that voltage and current frequently are not in phase.

Much of mankind is out of step with the deeper trends of its time. In 1947 we find ourselves trying to make a peace which would have been possible and appropriate in 1919, but now is nearly as outmoded as the weapons of the first World War. Likewise, by incantation we are striving to perpetuate an era of copious employment, paying little heed to the subtler causes of modern trade recessions.

Science now is apotheosized as the great creator of jobs and the leaven which works irresistably for prosperity. "Only through research and more research can we provide the basis for an expanding economy, and continued high levels of employment,"—or so reads a recent Washington exhortation.

Contrarily, I say, let us, as technologists, assume our traditional critical attitude of mind. Let us scan anew our readings of old texts. At the very least, these may require reinterpretation in the light of changed world conditions.

## REPORT OF THE STEELMAN COMMITTEE

An intentionally impressive document, but recently released from Washington, contains a startling formula for national security and prosperity. It undertakes to see the future in the past, prescribing old remedies for new social maladies, not admitting that history most often fails to repeat itself when we most expect it to do so. I refer to the so-called Steelman report entitled, "Science and Public Policy." It echos the confidence in science which recently has become well entrenched in the public mind, largely in consequence of what scientists, irrespective of nationality, were able to accomplish in the war effort.

The authors of the report (and presumably its sponsors as well), having observed that in industrial circles there has sprung up somewhat of a vogue to measure the adequacy of a technological research budget by the ratio it bears to the operating revenues of a company, undertake to generalize this empirical relationship by declaring that the nation as a whole should spend, henceforth, about the same fraction of the national income on scientific research.

They remark (page 26), "Many industrial concerns devote two per cent of gross sales income to research and some of the more progressive firms spend from four to six

R. W. King is assistant to the president, Bell Telephone Laboratories, Inc., New York, N. Y.

per cent. The nation could profitably devote more than one per cent [of national income] to these purposes; it cannot safely spend less.". . .

"Expenditures for basic research should be quadrupled and those for health and medical research should be tripled in the next decade, while total research and development expenditures should be doubled," says Washington.

Of course, the suggested analogue between the nation and an industry breaks down at once; or, rather, does not exist. Gross sales or operating revenue (by using the term "gross sales income," the authors of the report seem to have sown the seeds of their own confusion) in the case of a corporation is one thing and income, proper, is quite another. Likewise, national income, comprised as it is of separate incomes of its individual economic units, though it bears some obscure relationship to total market sales (that is, the summation of individual gross sales) is of a different order of magnitude. The line of argument in "Science and Public Policy" is akin therefore to deducing that, because an apple may hold 12 seeds, a peach ought to have 12 pits and a cow bear 12 calves in a "litter."

The authors of the report are untroubled, moreover, by the pyramiding of research effort which their proposal would entail. They are enthusiastic, rather than disturbed, that the application of their formula would step up the nation's research and development tempo as rapidly and to about the full extent that young people of college age could be switched to technical courses and then graduated. They give no heed to the question whether the nation would gain or lose on balance when a first-rate lawyer, farmer, businessman, or housewife (because, in the program advocated, women more and more will be drawn into the technological vortex) is turned into a second-rate scientist. Blithely, they conclude that because a vitamin pill or two are good, a great many must be better, even to the extent that one skimps on calories to buy more pills.

Only one supportable reason does the report give for such an expanded program of science, and this is a gloomy reason indeed. It concerns the foreboding that much future research may be conducted behind locked doors; in Russia, such is rumored to be the case already, with heavy penalties for the disclosure even of industrial results. Popular demand for retaliation could compel the American defense to be one of "following suit." Of course, no one can foresee the extent to which Russia's rumored secrecy program could play hob with long established and cherished practices of scientific freedom. It seems not unlikely, however, considering our own high-pressure programs in nucleonics and bacteriology, that we already have more work under secrecy order than the Russians. Perhaps, under the circumstances, we should prepare to launch a learned society to be known as "Scientists Anonymous." Then, official merit would go to engineers displaying the best poker faces; which points, in turn, to a field of college endeavor in which intensification of effort would dismay few students, and would make an erstwhile lowly extracurricular activity the basic prerequisite for all other courses.

Of course there is one broad area of science, the biological, in which any reasonably augmented program of research promises to be very constructive and with which no critic could quarrel. The sums, however, that could be spent in it effectively are trifling compared to those that the report recommends Congress appropriate. And though there are many promises of important advances in the study of life, these should not blind us to disquieting portents elsewhere, notably along the front where political developments meet the practical applications of the physical sciences. In this area our national affairs appear critical out of all proportion to the comment they have received, and official Washington, in so far as it exhorts to a greatly intensified effort in the physical sciences, tags in the rear of a long and justly honored procession, while its creed that advances in physical science make and insure adequate employment gives disturbing evidence of having outlived its usefulness.

## SCIENCE AND INTERNATIONAL AFFAIRS

No one needs to be reminded that a most serious contemporary danger concerns the revolution that science has wrought in warfare, thereby raising the poignant question as to whether any of us long shall stay alive. This fact by itself hangs a pall of doubt over the future of technology and over the roseate visions of its advocates. The irony of knowledge without an adequate leavening of wisdom is tersely summable in the observation that science and technology, while skyrocketing the cost of staying alive, have reduced the cost of mass destruction to the level of a beggar's mite. Yet Washington admonishes us to speed still faster the mill grinding out knowledge, while making no slightest suggestion as to how we should set about garnering the wisdom so desperately needed as a counterbalance. In fact, of the copious funds which the Steelman report would mobilize, not a penny would go to the study of social, political, and economic problems. Nor does the report give so much as a hint as to where these fields of vital learning should look for support.* Better if we ponder the recent remark of the Brazilian delegate to the United Nations, to the effect that "the people who have disintegrated the atom now have the mission to integrate humanity."

Of course the Steelman report stresses the continuing need for military preparedness and the great contribution which science must make in underwriting national security. Here, likewise, the report exhibits a somewhat stuffy lack of comprehension. The development of mass

* Volume 4 of the Steelman report, "Manpower for Research," gives a few words of recognition (page 2) to the alarming situation in which most privately endowed institutions of higher learning now find themselves and adds that "the broader aspects of this problem will be dealt with in the reports and recommendations of the President's Commission on Higher Education." These will may be awaited with interest. A portion of the report of this commission recently became available, but until its publication is completed comment appropriately may be withheld.

destruction weapons has gone far enough already to demonstrate to those of imagination that there are essentially but two choices before western man; one is the total abolition of war, the other is the wiping out of his cultural attainments and potentialities. If the former choice is grasped, the defense doctrine of the report stands as a repudiated vestige of the past. If, on the other hand, the way of national defense is chosen, then the chief preparation needed will be for most of us to prepare to die.

Let us, however, turn from world issues to seek an evaluation of technology within the domestic scene. This is appropriate since, if we entertain an optimistic attitude toward the unsnarling of the world situation—and certainly we might as well be optimistic though presently lacking any substantive basis for hope—we still shall have to reckon with the powerful manner, though slow, in which technology is molding the nation's economy and polity.

## A TIDE IN THE MAKING

We are greatly concerned with the spread of collectivist ideas generally, and of communism in particular, yet fail to note that, in large part, these are the direct product of a technological economy.

In the first place, most of the leading nations have had their ties with the past irrevocably broken by technology. Moreover, in the vast but relatively undeveloped countries, China and Russia, the war has strengthened greatly the national desire for industrialization along occidental lines. This desire is not balanced by any true popular appreciation of the slow steps by which the nations that, for a century or more, have led the industrial vanguard, have undergone their economic evolution. Naturally, without this stabilizing background, the popular pressure to achieve industrial miracles is enormous, and the dearth of capital and of professional personnel is such that only a collectivist or socialistic approach to the task gives any promise of quick results.

How natural the collectivist approach is perhaps can be appreciated better by supposing for the moment that the United States were suddenly to find itself without basic industries, yet possessing relatively complete knowledge as to how to set them up and operate them. Then our problem would not be one of inducing timid venture capital to risk itself. Rather, with an already assured market and an impatient public clamoring for service and supplies, it would be to find the necessary technicians, sufficient amounts of capital, and adequate manufacturing facilities to satisfy the pressure of the demand.

Several large nations are in this very situation. They really have no alternative comparable to the adoption of a collectivist program whereby the state, through regimentation of workers and the exercise of its large public credit, can undertake to make good the basic shortages as quickly as possible. Were there no other reasons for the present ideological differences between, say Russia and ourselves, this alone would cause our late ally to favor a position well over to the left. The situation in China cannot be greatly different, while even in several European nations there is excellent soil, technologically prepared, in which the seed of collectivism can flourish. And though we shudder at the rise of political regimentation abroad, we in fairness must see ourselves as victims of a regimentation which also takes its rise from the exactions of the highly mechanized state. Within the framework of what was originally a simple representative government, a matted undergrowth of bureaus and commissions has sprung up, with authority more and more to make the rules and issue the decrees by which we must order our lives. Staffed for the most part by professional politicians, their activities now cover so vast a range that the average citizen feels himself incompetent and hopelessly unable to organize against them; while Congress operates under such a crowded calendar as to find scant time to exercise its prerogatives of surveillance. Indeed, we begin to see that the function of public management, as assumed by government, recruits to itself particularly from the category of individuals who esteem public power; who, in fact, rate it above financial emolument. The growing number of persons of this turn of mind in government bureaus adds greatly to the latter's potency but not always to their judicial balance. Having entered the service to gratify the desire of holding and wielding political power, they instinctively use their influence and entrenched position, together with the broad and frequently ill-defined powers which the Federal bureaus and commissions grant over the nation's economy, to draw such satisfaction unto themselves. And arrayed against these unified forces of government are usually but random and undisciplined ranks of private business, against which the technique of "divide and conquer" generally is distressingly effective, division usually being assured by the statutes forbidding combinations in restraint of trade.

## THE SOCIAL IMPORT OF SPECIALIZATION

Of late, it has become popular to admonish the scientist to leave his ivory tower and the engineer his workshop, and observe better how the world is faring under the impact of their technological achievements. But admonitions of this sort stop far short of the heart of the matter. In fact, they but draw attention away from the causes lying beneath the symptoms—away from the fact that the present principles and practice of organization harbor a fundamental weakness.

The rapidly growing intricacies of technology (as well as of business generally) have left the limited capacity of the individual mind so far in the lurch that supreme emphasis now rests upon organization. Hence, the insistent demand of the day is for more intensive specialization. It is the price of success in business, in science, in

engineering, in industry; in fact, in almost every walk of life. The road to material rewards and public recognition leads to the ever finer subdivision of tasks and the more precise delineation of duties. Every organization is a team of experts; and, in the world, as in a team, success depends chiefly upon each member enthusiastically and energetically fulfilling the functions assigned him. His not to reason why; his but to *do*, knowing that in this way he most surely will win the approval of the administrative levels above him, and that his reward will be most assured. The pressure of the assigned job leaves little or no time for intellectual gymnastics, including the appraisal of social consequences. Likewise, one's position in his business group depends chiefly upon his playing the game intensely with them, and he would lose rather than gain status were he to envelop his practical life in a shimmering integument of thought.

Technological man regards it as axiomatic that, whether his post be near the bottom or near the top, his duty is to think of his responsibility as circumscribed by the job assigned to him, his function being to push ahead as effectively as possible within the limits thus set. By common experience, the chief material rewards go to those who best execute their orders and whose attention therefore is distracted least by qualms of doubt. Those who achieve practical success do so on the basis of an understanding that it is not their duty to co-ordinate and evaluate remoter consequences, and in particular to be solicitous about what social values or weaknesses may reside in the effort as a whole.

While not everyone fits comfortably into this mold, the fraction who find extreme specialization so distasteful that they rebel against it is surprisingly small. Of course, throughout the ranks of labor generally there is small disposition to assume responsibility, and it is well understood that for many who choose a military life, a chief attraction is virtual freedom from responsibility.

But these areas, broad though they are, do not concern us in the present argument. Moral and ethical standards are made chiefly by men, who, for one reason or another, have been placed in positions of public confidence and leadership, and it is at these levels that the vigilance which should be eternal seriously is being challenged by the doctrine of limited responsibility.

A case marking an exception therefore deserves notice. Across the broad vista of American life, perhaps the freest worker of all is the pure scientist; yet he is by reputation rather indifferent to public causes. Special thanks are therefore due the atomic scientists for their continuing efforts to arouse the public to the crisis now inhering in man's control of nuclear fission.*

* But their word still has a long way to travel. Thus, the Compton Committee's report, "A Program of National Security," may provide, within limits, a formula for military defense of the territory of the United States, but in striving for this objective, they obligate the nation to expenditures and procedures that would entail the regimentation of taxpayers and industry alike. The program's subterranean factories and essential services, sheltered by heavy layers of concrete and lead, offer little assistance in protecting our liberal way of life; rather, one fears they merely provide a means for choosing one collectivist state as against another.

## THE PROGRESS OF SOCIALISM IN ENGLAND

Returning to the direct impact of technology upon political institutions, it is not surprising, human nature being what it is, that the advocates of collectivism cannot wait for this impact to accomplish their desired ends spontaneously. The behavior of the Fabian socialists in England is understandable upon this basis. It, likewise, is not surprising (though this fogs the issue and calls for comment here) that they have begun of late to bemoan in public the fact that elsewhere corrupt leaders are employing the high ideals and purposes of socialism to lead their people into political serfdom. Mr. Atlee sorrowfully notes that a section of a movement which began in an endeavor to free the souls and bodies of man now has been perverted into an instrument of their enslavement, and he warns that, without political freedom, collectivism quickly can go astray and lead to new forms of oppression and injustice.

Now the leaders of Fabian socialism are highly intelligent individuals—and doubtless very sincere as well—so that one must accord a certain respect to their opinion that socialism can lead, perhaps, elsewhere than to political servitude; or at any rate that the regimentation of Fabian socialism can be more agreeable and more stimulating than the regimentation of Marxian socialism. But grave doubts will abound until the English experiment gives a living demonstration of their theory.

The unmistakable fact is that, whether professedly under a democratic or a socialistic banner, the effective operation of any technological economy depends more and more upon closely knit relationships. The state, whether we wish it or not, is forced to assume much of the character of a factory, and will fail increasingly to meet the mass demands of its citizenry unless each component group or department is regimented to keep step with the ensemble.

In a factory teamwork is not achievable automatically, but springs from a recognized community of interest, a common objective, and supervision which—through properly maintained communication and a system of incentives and rewards—assures the needed balance and rhythm of effort. These are all difficult requirements for the liberal state to meet, and perhaps the most difficult of all is that of a common objective, though war unhappily serves in this respect more effectively than peace.

## THE BROADER PERSPECTIVE

When seen in perspective, the history of every liberal nation consequently appears as a series of political ice ages. Each national crisis, whether of war or trade, by challenging the institutions of free enterprise to the point of failure in one respect or another, has brought about an advance of the polar ice cap of political restriction which the intervening periods of recovery have been too short to thaw. This cycle is one which we must expect will recur more frequently, not less, as our technological

balances require—though they may not receive—finer equilibrating.

No aspect of the current scene, however, deepens one's concern for the future of freedom more than does the widespread willingness to believe that collectivism can provide a happier national estate and justify all its attendant risks. Evidence of it is found in a growing preference among the rank and file of workers (not alone government employees) for state security and for state guarantees behind their jobs. This frame of mind roots in the vicissitudes exhibited in economic history, and to it our elected officialdom has shown that it is peculiarly responsive. Hence it is, that the power to tax is being used to insure jobs; and when taxes no longer can provide the desired insurance along with the countless other growing obligations of every "liberal" government, it only will remain for the state to take over the erstwhile sources of employment, and taxes.

From the proposition, when so briefly and bluntly stated, many at first may withhold agreement. By way of verification, however, note that just now a seeming majority of American scientists, lovers of freedom par excellence, are demanding government support for their research. It is a disturbing spectacle, yet quite in harmony with the trend of our time. And if scientists quite generally, the intellectually elite, are so eager for government funds, and, at the same time, seemingly indifferent to the reasons why their former sources of support have dwindled dangerously, it betokens that, for the rank and file of citizens, promises of security and abundant employment, when made by the state, exert a great drawing power at the same time that they excite little or no suspicion.

What better epitome of the social and political confusion that technology has wrought?

We are entering upon the hour of decision! The doctrine that, if a nation will but put scientists to work at the taxpayers' expense, there will be "jobs for all, all the time," is certain to bear bitter political fruit. It is deceptively easy to drive ahead in science and its industrial applications, but correspondingly difficult to formulate a free and nonpolitical deontology. As we acquire firmer footing in the first area, we stumble into more ominous quicksands in the latter. In order better to comply with the demands of the machine, we unconsciously are fashioning our political prison. Not machine politics but machine-made politics should be our chief concern. Let us clearly understand the many ways in which technology encroaches upon political liberalism! The pattern of tragedy is being more and more surely defined, and from it no *deus ex machina* is likely to effect our liberation. So let all, even those of us who are engineers and scientists, renew the challenge:

> "For what avail the plough and sail,
> The land, or life itself,
> If Freedom fail."

# Electrical Essay

## Which Source Feeds Which Load?

Two similar batteries, $X_1$ and $X_2$, of the same voltage feed two equal loads, $R_1$ and $R_2$, by connecting wires as shown in Figure 1. The wires from $A$ to $B$, and from $B$ to $C$ are interlaced tightly so that very little magnetic field outside their neighborhood is produced by the interlaced wires. These wires are at nearly the same potential, so that the electric field between them is very feeble.

An electric power engineer and a radio engineer debate as to which battery feeds which load.

The electrical engineer, knowing that the energy flow

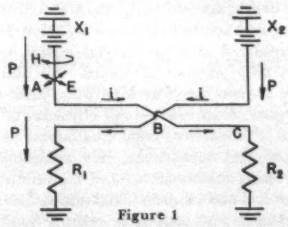



Figure 1

would be indicated by wattmeters, which, wherever they are connected, give the product of potential and current, traces out the wires, and concludes that battery $X_1$ feeds load $R_2$, and that battery $X_2$ feeds load $R_1$.

The radio engineer, however, just had been making some antenna calculations, and knows that electric energy flow is given by the Poynting vector, $\mathbf{P}=\frac{c}{4\pi}[\mathbf{E}\times\mathbf{H}]$, a vector which stands perpendicular to both the magnetic field intensity and the electric field intensity, and whose magnitude is proportional to the product of the magnetic and electric intensities and the sine of the angle between them.

The radio engineer readily constructs the Poynting vector for the lead coming from $X_1$. He finds a nearly equal Poynting vector in the same direction for the lead to $R_1$. However, for the twisted wires from $A$ to $B$, where the magnetic field $\mathbf{H}$ is strong, the electric field $\mathbf{E}$ is weak, and where the electric field $\mathbf{E}$ is strong, the magnetic field $\mathbf{H}$ is weak. He then only can construct a very feeble Poynting vector there, only enough to cover the losses in the twisted wires from $A$ to $B$. He finds entirely similar results for the Poynting vectors at $X_2$, $R_2$, and the twisted wires from $C$ to $B$. He, therefore, concludes that battery $X_1$ feeds load $R_1$, and battery $X_2$ feeds load $R_2$.

Who is right, the electric power engineer, or the radio engineer?

J. SLEPIAN (F '27)
(Associate director of research, research laboratories, Westinghouse Electric Corporation, East Pittsburgh, Pa.)

# The Heat Pump

THE ELECTRICAL UTILITY INDUSTRY is interested intensely in the heat pump because it holds promise of permitting the industry to supply domestic heating service in an economical manner. Until now it has supplied very little of this market and without the heat pump is not likely ever to supply very much of it.

Looking realistically at the problem, it would appear that a substantial amount of additional research is needed on the economical methods of utilizing available heat sources, on the engineering of economical heating media, and on the design, assembly, and operation of heat pumps, refrigerants, and accessory equipment, before this device can be considered as a commercial reality, within the reach of a large number of homes. To find popular acceptance it must have at least nine basic qualities: high reliability of operation, high efficiency of performance, low maintenance cost, reasonable first cost, compactness, neat appearance, easy accessibility of all parts for repair, maintenance, and replacement, minimum noise level and vibration, and adaptability to wide application in new as well as in existing home heating systems.

## The Utility's Perspective

S. W. ANDREWS
ASSOCIATE AIEE

THE HOME-HEATING MARKET is a big one. It has been estimated that the heat required for domestic house heating, if translated into kilowatt-hours of electric energy, would amount to 700 billion, as compared with the total sales of electric energy in the year 1945 to residential customers of 34 billion kilowatt-hours. A market of this size naturally holds out great attractions to the utility industry if it can be developed in a manner which will be advantageous to the supplying companies, to the manufacturers of equipment, and to the customers themselves.

Based upon one technical paper and three conference papers: 48-93, "The Heat Pump From the Utility's Point of View," by S. W. Andrews; "The Heat Pump—Its Significance as a Potential Residential Electric Load," by Constantine Bary; "Some Aspects of Engine Drives for Heat Pumps," by K. W. Miller and N. C. Penfold; and "Climatic and Usage Factors Affecting Heat Pump Economics," by D. W. McLenegan and G. W. Brown; all presented at the AIEE winter general meeting, Pittsburgh, Pa., January 26–30, 1948. The technical paper is scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

S. W. Andrews is a rate engineer with the American Gas and Electric Service Corporation, New York, N. Y. Constantine Bary is a rate research engineer with the Philadelphia Electric Company, Philadelphia, Pa. K. W. Miller is assistant director and N. C. Penfold is chairman of mechanical engineering research at the Armour Research Foundation, Chicago, Ill. D. W. McLenegan is assistant to manager of engineering, and G. W. Brown is commercial engineer in the air conditioning department of the General Electric Company, Bloomfield, N. J.

Constantine Bary acknowledges the valuable suggestions received from N. E. Funk (F '34, past president), L. L. Craig (A '09), E. H. Bromer, A. H. Kidder (M '39), and G. E. Klapper, of the Philadelphia Electric Company, Philadelphia, Pa., concerning the original manuscript of his article, and the assistance of A. Abramovitz of the Philadelphia Electric Company, in preparing the material contained therein.

### WHY HAS ELECTRICITY NOT DOMINATED THE DOMESTIC HEATING MARKET?

Up to now the only available way of heating buildings by means of electricity is with a resistance-type heater. This may take the form of the small familiar socket appliance with a reflector, a unit built into the wall of a room, an electrically heated steam or hot water radiator, a panel-type radiant heating system, or central heating units which are installed in a duct system supplying an entire building. These arrangements may be low in first cost from the customer's point of view, but the cost of supplying electric energy to a resistance-type heater used for space heating is high.

If an electric utility company generates most of its energy from fuel, the basic source of heat liberated in the house by a resistance heater is the fuel which is burned in the power plant. Even in the most efficient modern fuel-burning generating stations, only about one-third of the heat energy in the fuel which is burned in the boilers can be converted into electric energy. With a modern fuel-burning system, the customer can achieve without too much difficulty a fuel efficiency of 50 to 70 per cent. Thus, from the point of view of fuel efficiency, electric heating with resistance heaters has a basic disadvantage not readily to be overcome.

Regardless of whether the utility company generates its energy from fuel or from water, there is another difficulty in supplying electric heat by space heaters. The annual load factor of heating load is very poor and has been estimated at from 10 to 20 per cent in different parts of the United States, depending in general on the latitude and, therefore, on the amount of heating service to be supplied. Low load factor business considered by itself is very costly for an electrical utility to furnish because of the heavy fixed charges which have to be met on the facilities necessary to supply the service.

For these reasons electric house heating by space heaters is not likely to be widely attractive to customers, because the customer probably always will have to pay substantially more for the electrical service than for some other competitive form of heat, without any comparable advantages to offset the extra cost.

### WHAT IS THE HEAT PUMP?

Basically, the heat pump is an electrically-driven compression-type refrigeration machine. During the heating season it is arranged to take heat from a low temperature source outside the building to be heated, raise the

temperature of the heat, and release it in the building. During the cooling cycle the operation of the unit is reversed so that heat can be taken from the building and released outside. This can be accomplished either by reversing the flow of the refrigerant, thus changing the condenser to an evaporator and the evaporator to the condenser, or it can be accomplished by changing the flow of the medium, air or water, which is used to carry heat into or out of the building, so that the medium which releases heat in the house by flowing over the condenser during the heating season is redirected to flow over the evaporator during the cooling season.

**A symposium on electric house heating at the AIEE winter general meeting placed special emphasis on the heat pump. The four papers presented aroused widespread interest and discussion. Although future prospects are encouraging, continued fundamental research is necessary with particular investigation of the characteristics and relative costs of various heat sources.**

In considering the heating cycle, heat pumps may be arranged to take heat from the outside atmosphere, from a well, from ground water, from a city water supply, or from the ground itself. Heat may be released in the house in the form of hot air or hot water, but with present types of equipment it may not be released in the form of steam, because temperatures high enough to generate steam cannot be achieved economically on the discharge side of the unit.

## WHY DOES THE HEAT PUMP ALTER THE RESIDENTIAL HEATING PICTURE?

The heat pump takes heat already in existence and transfers it from the outside of the house to the inside. It therefore results that the electric energy which drives the machine does not have to supply all or even a major part of the heat which is liberated inside the house. The amount of heat which is liberated in the house compared with the heat equivalent of the electric energy used to drive the machine, or the coefficient of performance, is always a figure greater than one and it will vary from two to as high as six or seven, depending upon the temperature of the heat source and the temperature at which heat is liberated. The closer these two temperatures are, the higher the coefficient of performance and, conversely, the greater the difference between them, the lower the coefficient of performance. Therefore, the coefficient of performance of the unit will vary throughout the year.

In other words, by taking two-thirds of the heat from the source outside the house and one-third from the electric energy used to drive the machine (assuming an average coefficient of performance of three), the house receives just about the same amount of heat which was available in the fuel which was burned in the generating plant to produce the energy necessary to drive the heat pump. The competitive situation is improved very materially as compared to what it is with the resistance-type heater.

Add to this the fact that the heat pump with a coefficient of performance of three to one takes only one-third as much electric energy and creates an electrical demand only one-third as great as would a resistance heater. Furthermore, inasmuch as the heat pump can be reversed and can operate to cool a house, it is a unit which operates 12 months in the year instead of just a few months during the heating season. The annual load factor is improved greatly and is perhaps brought up to figures of 25 per cent to 35 per cent in various parts of the country and the unit cost of energy to be delivered to the customer thus is reduced still further.

## IS THE HEAT PUMP READY FOR PRODUCTION?

There are a considerable number of heat pump units in operation both in the United States and in parts of Europe. Before World War II, most of the installations were custom-built jobs. They were installed mostly in buildings larger than residences and they specially were designed and engineered for a particular job. For the most part they took existing component parts and brought them together into workable systems.

Since World War II, there have been a few manufacturers who have built some units for domestic purposes. These have been, to a considerable extent, simply assembled jobs in which the manufacturer brought together the component parts which he could buy on the market or some of which he may have made himself. There are only about 200 or 300 of these units actually in service, all of which have been treated to some extent as developmental experiments. Units specially designed and specially engineered for household heating which would give high coefficients of performance and be reasonably trouble-free as is the familiar electric refrigerator now are being developed by several manufacturers.

There is a lot of work still to be done before we get to the day when Mr. or Mrs. Customer can walk into a heating contractor's establishment and buy the right kind of unit for his or her own house with every assurance that it will perform as advertised. Although the prices cannot be set until development is more complete, it would seem that the cost of a heat pump unit should be less than a separate fuel-fired heating system plus a conventional cooling system.

It is likewise impossible to venture a guess as to what ultimate electrical rates would be for service to heat pumps. It is probable that initially at least electrical service can be supplied for heat pump installations under the standard rates available for the customer's regular service. As time goes on and more experience is gained,

electrical utilities naturally will review the load characteristics of house heating service and will relate these to the cost of supplying the service and, as time goes on, electrical rates for house heating service should find their own proper level, just as has been the case in years gone by in the supplying of service to electric ranges, refrigerators, water heaters, and the many other types of load which are supplied by electrical service.

# Its Significance As a Potential Residential Load

CONSTANTINE BARY
MEMBER AIEE

THE fundamental thermodynamic principles of the heat pump have been known for almost a century. Its operation on the cooling cycle has had extensive practical application in refrigeration, and in air conditioning of homes and other buildings. But, because of many technical difficulties and relatively high first cost, its operation on the heating cycle has had only limited application.

But, notwithstanding the difficulty of foreseeing the future clearly and the futility of trying to determine precisely the world of tomorrow, it nevertheless seems highly desirable to obtain some idea now on the possible effects of the future residential heat pump load, so that the electrical industry can continue discharging its responsibility to broaden its usefulness, just as in the past.

## GENERAL THERMODYNAMIC PRINCIPLES OF HEAT PUMP OPERATION

Figure 1 illustrates the well-known relationships of efficiency and coefficient of performance of an ideal Carnot heat engine, and that of a heat pump reflecting the ideal Carnot cycle of operation. In this figure, $T_1$ and $T_2$ are absolute temperatures, with $T_1$ being higher than $T_2$; $Q_1$ and $Q_2$ the quantities of heat received from, or exhausted to, some outside body, and $W$ the work done by or on the system.

It will be noted from the formulas shown that because the difference between the temperatures $T_1$ and $T_2$ is always less than $T_1$, the coefficient of performance of a heat pump operating on a heating cycle will be always greater than unity. By algebraic transformation it may be shown too that for given temperature levels, the coefficient of performance for the heating cycle ($COP_h$) is equal to one plus the coefficient of performance for the cooling cycle ($COP_c$).

Figure 2 illustrates by means of a pressure–enthalpy diagram, the fundamental thermodynamic principles of operation of a heat pump on an ideal vapor cycle, with its irreversible processes, employing as a working medium a fluid which can be made to absorb and surrender heat by an alternate process of vaporization and condensation.

The coefficient of performance of the actual cycle of a heat pump will be lower than that of the ideal by the high and low side frictional pressure drop losses occurring in the actual cycle, the electrical losses of the motor driving the compressor, and the mechanical losses of the compressor. However, some of this decrease in the actual coefficient of performance may be offset by employing liquid-subcooling and liquid-suction vapor heat exchange.

Expressing these effects in terms of factors for application in the coefficient of performance formula of the ideal cycle, the formula for the actual cycle with subcooling and liquid suction heat exchange becomes:

$$COP_h = 1 + e f_l f_h z \frac{h_1 - h_2}{h_3 - h_2}$$

Where

$e$ = the isentropic efficiency of the compressor-motor combination
$f_l$ = the low side pressure drop correction factor
$f_h$ = the high side pressure drop correction factor
$z$ = liquid subcooling and vapor heat exchange correction factor

Under a proper design and within the practical range of heat pump operation the factors $f_l$ and $f_h$ will be always lower than unity and the factor $z$ will be generally higher than unity, with their product approximating unity. Therefore the isentropic efficiency of the compressor-motor combination is left as the major determining factor in establishing the coefficient of performance of an actual cycle as compared with an ideal one.

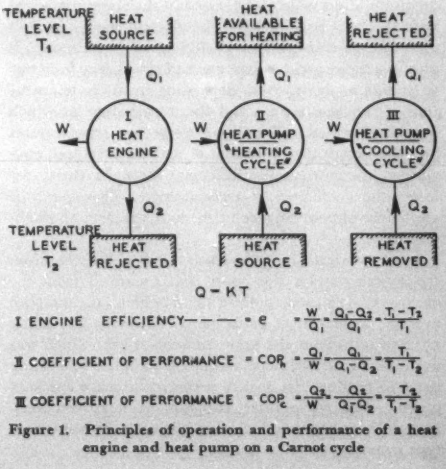

TEMPERATURE LEVEL $T_1$
HEAT SOURCE
HEAT AVAILABLE FOR HEATING
HEAT REJECTED
$Q_1$
W
I HEAT ENGINE
II HEAT PUMP "HEATING CYCLE"
III HEAT PUMP "COOLING CYCLE"
$Q_2$
TEMPERATURE LEVEL $T_2$
HEAT REJECTED
HEAT SOURCE
HEAT REMOVED
$Q = KT$
I ENGINE EFFICIENCY $= e = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1} = \frac{T_1 - T_2}{T_1}$
II COEFFICIENT OF PERFORMANCE $= COP_h = \frac{Q_1}{W} = \frac{Q_1}{Q_1 - Q_2} = \frac{T_1}{T_1 - T_2}$
III COEFFICIENT OF PERFORMANCE $= COP_c = \frac{Q_2}{W} = \frac{Q_2}{Q_1 - Q_2} = \frac{T_2}{T_1 - T_2}$

**Figure 1. Principles of operation and performance of a heat engine and heat pump on a Carnot cycle**

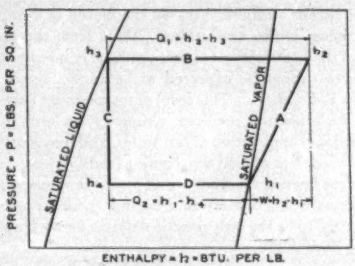



**Figure 2. Pressure–enthalpy diagram of ideal vapor cycle for heat pump operation**

$$COP_h = Q_1/W = \frac{h_2 - h_3}{h_2 - h_1}$$

$$COP_c = Q_2/W = \frac{h_1 - h_4}{h_2 - h_1} = \frac{h_1 - h_3}{h_2 - h_1}$$

*A—Isentropic compression*
*B—Constant pressure condensation*
*C—Constant enthalpy expansion*
*D—Constant pressure evaporation*

In actual practice, in addition to the electric energy requirements of the compressor-motor, there may be energy required for auxiliaries such as fans and pumps which are functional parts of the heat pump. The energy used by them must be considered in establishing the over-all coefficient of performance of a heat pump assembly.

## HEAT SOURCES

Because the coefficient of performance depends upon the difference between condenser and evaporator temperatures, the temperature characteristics of heat sources become of major significance in the practical performance of heat pumps, and the temperature levels of heat distribution media become of great importance in the design of the heating system employing a heat pump.

There are three principal heat sources available to a heat pump today: air, water, and earth. They may be used separately or in combination. Each has its own physical and economic advantages and disadvantages.

The air possesses the advantage of being universally available, free of charge. However, possible wide fluctuations of its temperature, and especially the level of its dew point temperatures, are limiting factors in its universal use as a practical heat source for heat pumps. Its temperature is lowest at times when house heating requirements are at a maximum, which is obviously the reverse of what is required to limit the size of installed capacity of the heat pump and to obtain the highest coefficient of performance. It is for this reason that the practical application of air as the sole source of heat for house heating at present is limited to climates where the temperature does not drop much below 35 to 40 degrees Fahrenheit. However, in climates where the temperature drops below those values, for part of the total heating season, it still may be an economical source of heat for the heat pump in combination with another heat source, which would be called upon, at intervals, to supply either the deficiency in, or even the total heat of, the requirements during that time. In a climate such as is experienced in the Middle Atlantic states, about 50 per cent of the heating requirements, as measured by degree days for an average heating season, occur at times when the daily mean outdoor temperature is 35 degrees Fahrenheit and higher.

Water from a flowing stream, from wells, or from city water mains is a good source of heat. It possesses the advantage of a relatively high temperature which is not subject to very wide fluctuations, but its disadvantages are that it is not universally available free of charge, and its use, in comparatively large quantities is undesirable, and usually entails costs which often are so high as to make it prohibitive from an economic and competitive point of view.

The earth several feet below the surface also has good possibilities as a source of heat for a heat pump. It possesses the advantage of having relatively high temperatures which are not subject to very wide fluctuations. But, at present, there is not too much known of its heat transfer characteristics at various levels, for different soil types, moisture content, and the different conditions of extraction and dissipation under varying temperatures; and the ultimate effects of unbalanced heat withdrawal from, and absorption by, the earth upon its long-term

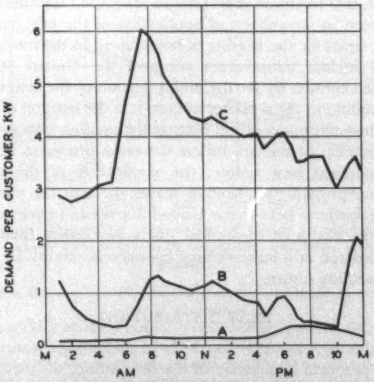



**Figure 3. Typical average weekday load curves for the coldest week of winter period**

*Based on one-half hour integrated demands*
*A—Ordinary use (lighting, miscellaneous appliances, and refrigeration)*
*B—Heavy use (ordinary use plus electric range and water heater)*
*C—All-electric (heavy use plus heat pump)*

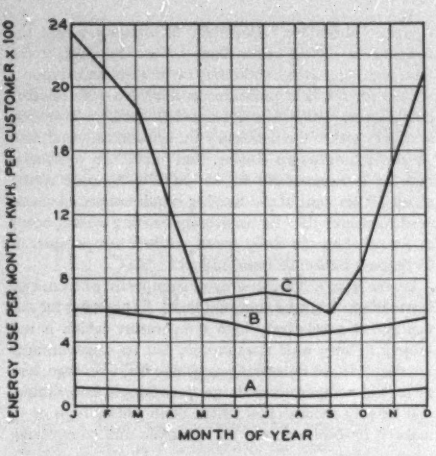



**Figure 4. Typical monthly distribution of annual energy usage**

*Three types of residential customers defined in Figure 3*

temperature levels are a matter of conjecture now. Its disadvantages are that this source is not universally available in the quantities and qualities required, and heat from it cannot be obtained free of charge, as work would be needed to embed into the earth at the desired depth necessary lengths of piping for the purpose of heat extraction or dissipation, as the case may be. The possibilities for its use as a heat source are so attractive, however, that in recent years they have aroused considerable interest in the subject of application of the heat pump principles for the heating of homes even in the northern and middle temperature zones of the United States which contain by far the major portion of the country's population. As a matter of fact, it is the opinion of the author and many others that, at the existing state of development of the art, unless the earth proves to be an economical heat source, the application of the heat pump principle for heating homes through the middle and northern belts of the United States can be relegated to the realm of theoretical discussion rather than be considered as a large volume commercial reality for the immediate future.

## HEAT DISTRIBUTION

Although the heat source is of major significance in the practical application of the heat pump, the medium employed for conveying the heat throughout the house is equally significant because the higher the temperature of the condenser, the lower the coefficient of performance. The temperature level in the condenser coils is limited by the existing availability of refrigerants and by the practical considerations of higher pressures (required by the higher temperatures) on the design of compressors, piping, joints, and valves. Thus, from the standpoint of the heating cycle alone, practical condenser temperatures cannot be expected to be much above 120 degrees Fahrenheit. This level of temperature rules out steam for a heating medium, circumscribes greatly the conventional application of hot water, and frequently requires a redesign of heat distribution facilities when using air for the heating medium; and from the standpoint of the cooling cycle, the air as a cooling medium appears at this time to be the only practical means for accomplishing the desired job.

## EFFECTS ON RESIDENTIAL LOAD CHARACTERISTICS

Although the use of the heat pump for the heating of homes at present is far from a commercial and large volume reality, it possesses so much appeal to the popular mind on its cleanliness, convenience, and year-round job of automatic air comfort in the home, that it cannot be ignored by either the utilities or manufacturers of equipment as to its future possibilities and probable effects on the load characteristics of the utility supplying the electrical service for its operation. The potential magnitude of this load is great as evidenced by the fact that, if only ten per cent of the residential customers of a large electrical utility system operating in the Middle Atlantic States were to be equipped with this device, under the performance levels now thought possible, there would be obtained an addition to that system's peak of about one-sixth of its entire 1947 peak load from all classes of service. This increase in system peak is about equal to the peak load of the entire residential class of customers represented by that community of some three million people. Obviously, a potential load of this magnitude deserves careful study as to its economic implications, especially since, in addition to its size, all indications are that its annual load factor and group coincidence factor will be much different from those experienced by the present size and volume load of the residential class of customers.

**Table I. Electric Load Characteristics of Three Types of Average Residential Customers**

| | Type of Average Residential Customers | | |
|---|---|---|---|
| | Present-Day | | |
| | Ordinary-Use A | Heavy-Use B | All-Electric C |
| Annual energy usage, kw-hr | 1,100 | 6,300 | 15,300 |
| Annual diversified 30-min integrated demand, kw | | | |
| Winter avg weekday max | 0.35 | 2.0 | 6.0 |
| Absolute max | 0.41 | 2.1 | 7.0 |
| Annual noncoincident 30-min integrated max demand, kw | 1.0 | 5.0 | 12.0 |
| Annual diversified load factor, per cent | | | |
| Based on winter avg weekday max demand | 35.9 | 36.0 | 29.1 |
| Based on absolute max demand | 30.6 | 34.2 | 25.0 |
| Coincidence factor, per cent | | | |
| Based on winter avg weekday max demand | 35.0 | 40.0 | 50.0 |
| Based on absolute max demand | 41.0 | 42.0 | 58.3 |

There is no precise way to determine the average size of the house heating heat pump load which may be served in the future by any given utility system because of the many variables involved in such a determination. At the beginning, and for many years to come, until substantial levels of saturation of this device are obtained, the average size of heat pumps may vary from year to year, depending upon the kind of homes in which they will be installed, the relative penetration of the various segments of the residential market, and the types of heat pumps used.

If past experience in the acquisition of the gas space heating load is any indication of the probable trends in the acquisition of the residential electric heat pump load, one may expect, at the start, the average size of heat pumps to be comparatively high, gradually decreasing with an increase in the saturation of this device. The capacity of the average heat pump used herein is based on a size house with a heating requirement of 55,000 Btu per hour for a 70-degree-Fahrenheit differential. But to assure adequate heating service, practical necessity will require that the heat pump capacity be greater than this requirement. The margin required is, at this time, only a matter of opinion. The economics of heat pump installations may preclude the use of any wide margins, and users of heat pumps may have to be taught to use this device differently from conventional fuel-fired heating installations. But for the purpose of this paper it will be assumed that an average home with the previously-described heating requirements will use a heat pump installation of 85,000 Btu per hour capacity at an outdoor temperature of zero degrees Fahrenheit. Its electric input will be close to 7 kw. Assuming the annual coefficient of performance to be $3^1/_2$ also such a heat pump on its heating cycle of operation would require about 8,200 kilowatt-hours for a normal heating season. For its cooling cycle of operation during a normal summer season it would require an additional amount of some 800 kilowatt-hours, based on results of tests made by the author in this territory on central system air conditioning installations in homes. The total electric energy consumption of such an average heat pump installation in this territory should thus be close to 9,000 kilowatt-hours for a normal year-round job of heating and cooling. The net additional amount of electric energy requirements, however, will be somewhat lower, because of displacement of existing electric equipment used in the home in connection with fuel-fired furnaces and summer ventilation. However, these effects will be neglected for purposes of this discussion.

The 30-minute maximum demand of an "average" heat pump will be assumed to be 7 kw. The corresponding diversified maximum 30-minute demand of this load on an average day of the coldest week in a year, approximating a daily mean temperature of 22 degrees Fahrenheit, will be around 4.9 kw per average installation, based on results of actual tests conducted by the author in this territory on residential gas space heating loads. In actual practice, however, it may be either higher or lower depending on the design of the unit, its relative efficiency of performance on cold days in comparison with the over-all record for the entire heating season, and upon the manner human beings choose to operate it: whether at a constant temperature setting of the house thermostat throughout the entire day or whether at one setting during daytime and a lower one at night.

Figure 3 compares the typical winter period load curves for three types of residential customers. The present saturation of electric ranges and water heaters* in this territory is relatively low, so that consideration of the size load of the all-electric customer of some 17 times that of the ordinary-use customer is more indicative of the magnitude of the problem faced by the utilities in meeting the requirements of this potential load by providing the necessary facilities in distribution lines, transformers, substations, transmission, and generation than a comparison of it with the heavy-use customer. From this chart it will be noted, too, that the peak load of the all-electric customer will occur in the morning, around 8 a.m., and that the load between 5 and 6 p.m. (the period of the present-day peak load of the residential class) will be about 65 per cent of the morning peak load, thus indicating that the heat pump load possesses diversity with respect to the present-day peak load of the residential class. Figure 4 shows an illustrative comparison of the relative monthly distribution of energy requirements of the three types of customers throughout the

* All reference to water heaters in this article apply to single-element heaters which operate on a time-controlled basis, the elements being disconnected from the electric supply from 4 p.m. to 10:30 p.m.

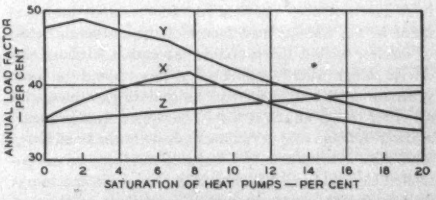



**Figure 5. Illustrative relationships of trends in residential class annual load factors with increasing saturation of heat pumps**

*Based on maximum diversified demands of average weekday for the coldest week of winter period*

*X—Addition of all-electric customers with heat pumps to a residential class consisting of ordinary use customers*

*Y—Addition of heat pumps to a residential class consisting of ordinary use customers with a 50-per-cent electric range and 25-per-cent electric water heater saturation*

*Z—Addition of heat pumps to a residential class consisting of heavy use customers (100 per cent electric range and water heater saturation). Curve Z reaches a maximum load factor of 40 per cent at 25 per cent heat pump saturation and thereafter decreases in a manner similar to the decreasing portion of curve X*

year. Table I shows that the annual energy requirements of the all-electric customer are estimated to be about 15 times that of the ordinary-use customer, and about $2^1/_2$ times that of the heavy-use type and that the annual load factor of an average all-electric customer with a heat pump will be lower than that of either the ordinary-use or the heavy-use residential customers, and that the coincidence factor of such a customer will be higher than that of both of these types. However, these comparisons alone are not fully indicative of the significance of the heat pump load because they fail to reflect the effects of the diversity which would exist between the peak load of an average all-electric customer having a heat pump and the peak load of the present-day residential class. To illustrate this latter effect, Figure 5 is presented. It shows the progressive change in the annual load factors of the entire residential class load with an increase in the saturation of all-electric customers having heat pumps and with an increase in the saturation of heat pumps for a given saturation of electric ranges and water heaters.

Among the many factors which enter into the appraisal of the economic significance of a given load supplied by an electrical utility, the annual load factor is of major importance. It is a well-known fact that, with all other things equal, cost per kilowatt-hour of supplying electrical service varies inversely with load factor in accordance with the laws of a hyperbola. The higher the load factor, the lower the unit cost per kilowatt-hour, and conversely, the lower the load factor, the higher such unit cost becomes.

The facts depicted in Figure 5 lead to the unavoidable conclusion that for electrical utilities in the United States, geographically located in the latitude of the system referred to in this discussion, the heat pump load does not offer possibilities of substantial improvement in the annual load factor of the residential class of service, within the probable saturation levels of this device which may be expected to be attained for some years to come. This fact, in turn, indicates that, with all other things equal, it would be impractical to justify a lower average rate per kilowatt-hour to the heat pump load than is obtained now from the addition of uncontrolled electric loads of other major usages in the home. As a matter of fact, under certain conditions, to cover all costs for the load factors of the residential class obtained with the heat pump, the average rate per kilowatt-hour applicable to this device may have to be even higher than is now generally available for uncontrolled usage of electrical service in the home at the prices of the end blocks of residential rates. These prices now average over 1.7 cents per kilowatt-hour in the 16 largest cities of the United States, in the northern and middle temperature zones.

The inherent lack in ability of the heat pump by itself to improve the residential class annual load factor, at least insofar as these zones are concerned, and its relatively large requirements for the supply of electrical service, emphasizes the necessity for a proper engineering and design of the various component parts of the device to obtain maximum efficiency of performance, reliability of operation, and applicability in new and existing homes; and to minimize its first cost and all undesirable electrical features such as high-starting current, low-power factor, and high demand, which, otherwise, would have adverse economic effects upon the electric supply system and thus result in economic handicaps in the utilization of the electrical service by this device.

It should be noted, however, that, for utilities located in territories similar to that referred to in this article, the acquisition of the year-round heat pump load, with its inherently lower summer than winter electrical requirements, carries with it the ability to improve the economic significance of the residential summer air conditioning load which by itself in large quantities is not desirable, because of its low annual load factor. A proper implementation of the year-round heat pump load with additional summer air conditioning load for customers with conventional heating systems, will tend to improve the over-all economic significance of the combined residential heating and cooling loads.

# Engine Drives

K. W. MILLER
MEMBER AIEE

N. C. PENFOLD

LED by electricals, engineers generally have acquired the habit of considering the heat pump exclusively in terms of electric motor drive. It can be shown that a heat pump driven by a gas, gasoline, or Diesel engine has superior possibilities in many respects, including both first cost and operating costs. During the present active consideration of such innovations as radiant heating, resistance heating, solar heating, heat storage, use of ground coils with heat pump, it seems wise for electrical engineers not to overlook the merits of engine drive for heat pumps in seeking the best technical and economic combination of elements to comprise a complete winter-heating summer-air-conditioning plant.

When a heat pump is driven by an engine, the usually wasted exhaust and water jacket heat of the engine is available to carry part of the heating load during winter. Moreover, because this auxiliary heat supply may be inserted judiciously in the thermal circuit to reduce the temperature head against which the heat pump must operate, the coefficient of performance of the pump is improved considerably. For these reasons the compressor or heat pump capacity, and the capacity of the thermal reservoir from which the heat is pumped, both are reduced in size to about half that required for an electric motor-driven unit.

It can be shown (see Table II), quite conservatively, that an engine-driven heat pump would have an over-all

coefficient of performance of 1.5 referred to the heat content of the fuel supplied. This is about twice as good as can be realized by burning the fuel in a furnace.

## COSTS AND CAPACITY

If we assume that the engine fuel is ordinary city gas at a domestic cost of seven cents per therm (100,000 Btu), then with an engine drive and a coefficient of performance of 1.5, it will cost $0.467 per million Btu delivered into the building. With the motor drive and a coefficient of performance of 3.0, 97.8 kilowatt-hours are required per million Btu delivered. Therefore, electric current would have to sell at $0.0048—less than one half cent—per kilowatt-hour to compete with the engine-driven unit on an operating cost basis. These figures are exclusive of operating costs of the auxiliaries, fans, and pumps, which would be about the same regardless of motive power selected.

The heat pump "size" or compressor capacity required would be nearly equivalent to the shaft horsepower in the two instances. If we assume an electric motor efficiency of 85 per cent, then the motor shaft horsepower is $0.85 \times 1/3 = 28$ per cent of the mechanical equivalent of the total delivered heat. For the engine drive, the shaft horsepower is $0.20 \times 1/1.5 = 13$ per cent of the rate of heat delivery (where 0.20 is the portion of fuel energy delivered by the engine shaft). The ratio of these two values indicates that the size or capacity of the heat pump for winter operation is less than half as great with engine drive as with motor drive for the same output. The possible saving in first cost of equipment is obvious.

Because of a smaller temperature difference between evaporator and condenser temperatures required in summer, the coefficient of performance of the pump will be better in summer than in winter. Therefore, discarding engine exhaust and water jacket heat outdoors during summer (except for domestic water heat or perhaps refrigeration and cooking), the heat pump will be sized properly for summer load; not about twice too large as with a motor-driven unit in northern climates for domestic applications.

## HEAT SOURCE

There is a still further advantage in equalizing summer and winter loads carried by the heat pump itself. It seems probable that use of coils buried in the earth will become more prevalent in the future.

According to Table II the heat to be supplied from the "heat source" or thermal reservoir is $0.74 - 0.20 = 0.54$ out of a total of 1.50 or, in other words, only 36 per cent of the total heat delivered by gas engine drive. For the motor-driven unit $(3.0 - 1.0)/3.0 = 67$ per cent of the total delivered heat must come from the heat source. Therefore, engine drive makes only about half as much demand on the heat source.

This arrangement has two practical advantages. The heat to be taken from or added to the earth during the heating-cooling season is reduced by a factor of about two by the engine-driven heat pump. The heat withdrawn and heat added during the two seasons is more nearly equalized than for the motor-driven unit. These factors are both very important because heat diffusivity of soil is small. Large quantities of heat can flow only extremely slowly through earth for distances measured in feet. The cubic footage of soil which must be "thermally tapped" and the linear feet of buried coil or pipe required to do it would be decreased in a ratio of about two to one in favor of the engine-driven installation.

All factors have been selected quite conservatively in the foregoing comparison. For final comparison, of course, it would be necessary to recompute for several load and temperature conditions and integrate results over a complete winter heating season. A much better showing can be made, of course, by picking improved conditions. Some improvements actually could be realized in practice in large industrial or commercial installations. However, as indicated in the comparison, extravagant claims are not necessary to show the great advantages of engine drive for heat pumps.

## ENGINES

Probably the first question most engineers will ask about an internal combustion engine drive is, "Can it be made reliable enough?" This is certainly a logical question and one which must be answered satisfactorily before engine drive for heat pumps may be given serious consideration. Apparently, there is no reason why an internal combustion engine cannot be made which will operate for months without attention, with a reliability comparable to the compressor which is itself a reciprocating device.

Many of us are familiar with some old engine which gave yeoman service for a number of years—on a farm, an oil field, a ranch, or work boat—and this in spite of exposure to weather, poor maintenance, and general abuse. Such engines were usually slow-speed low-output units of high weight per horsepower and were unimpressive in appearance and performance. However crude, many of these engines had fair thermal efficiencies and operated on a wide variety of fuels. If such reliability could be obtained 20 years or more ago, present-day "know-how" certainly can produce a power plant of both acceptable reliability and economic manufacture, par-

**Table II. Heat Balances for Gas Engine**

| Heat Source | Amount | × | COP | = | Delivered Heat |
|---|---|---|---|---|---|
| Shaft power | 0.20 | × | 3.7 | = | 0.74, pump |
| Exhaust (800 F.) | 0.38 | × | 0.9 | = | 0.34 } |
| Water jacket (170 F.) | 0.35 | × | 1.0 | = | 0.35 } 0.76, waste |
| Radiation | 0.07 | × | 1.0 | = | 0.07 } |
| Total fuel value | 1.00 | | | | |
| Total heat delivered by engine unit | | | | | 1.50 |

ticularly for operation in a perfect environment indoors on a uniform "clean" high grade fuel such as city gas. Unfortunately, most engine builders' present efforts are directed towards light-weight high-output engines while only a few are attempting to favor reliability and long life in their design and construction practices.

## FUELS

The cost of available fuels largely would govern the selection of fuel for each particular installation. Distillates and Diesel fuel oils are the more likely to be used fuels of the liquid variety.

Gas as supplied through city mains, whether natural, manufactured, or mixed, is an excellent fuel, and house heating rates in most instances are attractive and, properly utilized, are competitive with oil and coal. Methane, a major constituent of natural gas, has a very high octane rating permitting use of high compression ratios.

Because these fuels are already gaseous, carburetors are not required and it is relatively simple to get uniform air–fuel mixtures and proper distribution between cylinders. Also, such fuel does not dilute crankcase lubricants as do most liquid fuels whose "heavy-ends" condense on cylinder surfaces and are scraped into the crankcase. Sulphur content of fuel gas (on a Btu basis) is generally much lower than that of liquid fuels, thereby reducing corrosive load on engine parts and exhaust piping.

## PACKAGED UNITS

The use of packaged power plants (or power plants and compressors) for heat pump application may have many advantages. Among these are

1. The engine may be a completely factory engineered-assembled-tested unit.
2. It readily may be installed or replaced by use of quick-disconnecting couplings.
3. A "leasing" arrangement may be worked out so that the user will pay a rental fee and the equipment supplier (or utility company) will furnish and maintain the installation.
4. Engines needing repair or replacement may be returned to a well-equipped shop for adjustment or overhaul where competent personnel are available to analyze trouble quickly and specify action to be taken.
5. Engine maintenance can be removed from the site of operation and "spares" be available so the user will not be without winter or summer air conditioning.

Packaged power units have been used to a limited extent in vehicular application and are enjoying increased popularity in railcar application for power generation and air conditioning.

## NOISE AND VIBRATION

Noise and vibration would be objectionable for any domestic application. However, with the availability of present-day sound absorbing materials and techniques, it is entirely feasible to design engines and mountings sufficiently quiet for domestic use.

## EXHAUST GAS COMPOSITION

Caution will be necessary in the confining and discharge of engine exhaust gases as these gases are toxic and generally have an objectionable odor whether they are from engines operating on the Diesel or Otto cycles.

However, when using city gas as the engine fuel, the exhaust gases contain far less of the obnoxious components and "fumes" than generally is associated with exhaust from Diesel and gasoline engines. Necessary precautions would not exceed those now customary in the operation of domestic gas-fired furnaces.

## CYCLING

It is known that engine wear rate bears a definite relation to number of starts and stops and that engines wear least when operated continuously above certain minimum speeds, loads, and coolant temperatures. Fully automatic starting of engines has been in common usage for a number of years and controls are readily available for this purpose. Refrigerant compressors may be equipped with unloading devices for easy starting of the driving unit which are common on electric units above certain sizes. It is possible that the engine and compressor be operated almost continuously during the cold and very cold months, by reducing engine and compressor speeds in accordance with the load demand. Moreover, it is important to note that necessity for part-load operation, cycling, or intermittent operation can be reduced greatly by large heat storage, which, indeed, the engine drive itself makes possible.

## HEAT STORAGE

Heat storage is important not only in greatly reducing frequency of cycling and coincidences of peak demand, but also in decreasing the capacity of the heat pump otherwise required for peak loads.

The engine-driven heat pump has a great advantage over motor-driven units in reference to heat storage. With a motor-driven unit the highest level of temperature which can be tapped for heat storage is the condenser at a temperature of about 120 degrees Fahrenheit. However, with an engine-driven unit exhaust heat is available in quantity at high temperatures, such as 800 degrees Fahrenheit for a gas engine. We shall assume that heat is usefully recoverable from storage at a minimum (emergency) temperature of 50 degrees Fahrenheit in any case. Water is the most practical storage medium in the low temperature range with motor drive, and loose, sized, crushed rock or coarse screened gravel with engine exhaust heat, these having thermal capacities per cubic foot of 62 and 22 Btu per degree Fahrenheit, respectively. Thus, with a motor unit we can store $(120-50)\times 62.5=4{,}350$ Btu per cubic foot, whereas with the engine-driven unit it is quite feasible to store $(800-50)\times 22=16{,}500$ Btu per cubic foot. This is a space factor ratio of about four to one in favor of the engine-driven unit for heat storage, exclusive, of course, of volume of thermal

insulation surrounding the heat storage water tank or gravel bin.

With a thermal capacity of 16,500 Btu per cubic foot for gravel or crushed rock operating between 800 and 50 degrees Fahrenheit, then it is feasible to store 3,500,000 Btu of usefully recoverable heat in a 6-foot cube of space. Allowing 6 inches wall thickness for thermal insulation, the over-all 7-foot cube (no larger than a coal bin) would fit easily in the corner of an average basement and would store enough heat to last a few days during an engine shutdown or to "take the curse off of" a few days of sub-zero weather so far as peak demand of the engine-driven heat pump is concerned. In a normal winter the cycling rate of engine operation could be reduced to a cycle or less per day.

For technical reasons, not elaborated here, it is possible to recover almost all the stored heat at full input temperature, that is, 800 degrees Fahrenheit. With heat stored at such high temperatures it would be a simple matter to install a loop coil near the outer insulating wall for water heating, and another loop coil for cooking in the upper hot portion of the crushed rock bed. With some of the newer circulating fluids now available, high temperature heat, suitable for cooking or for solution cycle refrigeration, could be obtained from the storage bed whether the heat pump is in continuous operation or not. With the storage bed initially entirely at the upper 800-degree-Fahrenheit temperature, 3½ million Btu would be available to carry cooking and water heating loads for weeks at a time in the spring and fall without operation of the heat pump at all. The bed normally would be operated during winter with nearly full heat storage to take care of infrequent outages and "cold snaps" in the weather. During the summer air conditioning operation of the heat pump, although not required for house heating, the heat storage bed also would be operated normally with full heat storage to take care of water heating, cooking, and/or solution cycle refrigeration loads and other service heat requirements as may be desired.

### BENEFIT TO UTILITIES

Almost all of the field trials, study, and promotion of heat pumps to date have been sponsored by the electrical utilities and this entirely on the basis of electric motor drive. This narrow viewpoint may be unwise even for their own selfish interests. Many electrical utilities are combination companies having extensive gas interests. For these the engines could be fed from the city gas mains and would give such companies excellent year-round commercial and domestic gas load by reducing the winter peak and filling in the summer "valley." Electrical utilities need not fear that their customers would put electric generators on the engine shaft for the units would "cycle" during the day, summer or winter, and would be idle days at a time in mild spring and fall.

For their own interests electrical utilities well may be advised to assist the development of the art into the most effective thermodynamic-economic channels even if by so doing they apparently are assisting competition. A motor-driven heat-pump unit is a luxury item. If engine-driven units gain acceptance ten times as rapidly or ten times in ultimate gross sales, what of it? The electrical companies would benefit by acquiring (as they always do) the highly desirable electric load of fan and pump auxiliaries, a nonconcentrated, good load factor, single-phase load, instead of reaping the disadvantages of relatively few scattered high power loads in domestic areas requiring 3-phase distribution not usually conveniently available or introducing serious problems of voltage regulation and lamp flicker caused by cycling of single-phase motors of a few horsepower rating.

The using public has a valid interest. It is entitled to engineering promotion and availability for purchase of units making use of component parts combining the best inherent, over-all thermodynamic and economic performance of an entire assembly. The social advantage of fuel saving and reduction of air pollution should be noted. Also, and quite important, many potential users in rural areas, such as on ranches and farms, do not have electrical supply now adequate, or economically feasible to make adequate, to carry a few horsepower load of a heat-pump air-conditioning unit. Many, of course, have no electric power supply at all. By use of an engine to power the unit, these potential customers can be served.

For all these reasons it appears that engineering study, research, and trial field installations of engine-driven heat pumps are well warranted, together with study of heat storage to reduce heat pump size, cycling, and coincidence of peak demands.

# Economic Effects of Climatic and Usage Factors

D. W. McLENEGAN
MEMBER AIEE

G. W. BROWN

IN MOST PARTS of the United States, heating plants must be adequate to heat our buildings from 0 to 70 degrees Fahrenheit. Actually this range varies with locality from a temperature difference of 100 degrees to one of only 35 degrees. It can be shown that the temperature span for heating, which largely determines size of plant, does not vary directly with the degree-day record (cumulative temperature deficiency below 65 degrees Fahrenheit). Even in the milder zones, heating requirements must include provision for occasional extremes of low temperature. The lowest recorded temperature need not be used as the basis for selecting building heating equipment, as this temperature minimum is approached only briefly and at long intervals. Through local experience, outdoor design

temperatures may be derived. For fuel-fired plants, the design temperature is usually about 15 degrees above the lowest recorded, except in mild-winter areas.

In summer, indoor temperatures usually are regulated by air conditioning to 15 or 20 degrees below the outdoor design temperature. Even higher differences commonly are maintained in dry locations such as Phoenix, Ariz., and Sacramento, Calif. Summer duty also includes an allowance for air drying, which in most regions adds substantially to the air-cooling load. Further, the intense solar radiation in summer adds to the cooling load. As a result the usual capacity required for summer air conditioning, from climatic conditions alone, is about the equivalent of 30 degrees of simple temperature reduction. This is about 40 per cent of the 70-degree heating span needed for heating service. Except for the extremes of north and south, this rough comparison defines fairly well the climatic balance between winter and summer capacity requirements.

Heat generated within a building must be considered particularly in establishing the capacity requirement for summer cooling. Even if such heat liberation is not continuous, it may be of sufficient rate and duration to require cooling capacity beyond that dictated by climatic conditions alone. In winter, such internal energy usage is seldom steady enough to be deducted from the peak heating requirement. Thus, internal heat sources may increase materially the ratio of maximum summer heat removal to winter heat addition rates. Examination of representative data indicates that the summer cooling to winter heating ratio for a residence is not greatly changed by the consideration of internal loads. However, in commercial buildings, higher occupancy and a higher load of lights and appliances usually do raise the ratio of summer to winter capacity requirements to a maximum summer heat removal of 70 per cent of the maximum winter heat addition, even in cold climates. This commercial air conditioning load balance makes for a more favorable summer–winter ratio of electric loads than can be anticipated in residences.

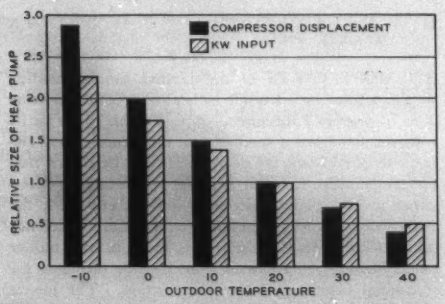



**Figure 6. Compressor displacement and power input for air-source heat pump vary inversely with outdoor temperature**

*To heat a given building without auxiliary heat storage. Requirement of building is assumed to increase directly with decreasing outdoor temperature*

## CAPACITY OF A GIVEN EQUIPMENT UNDER VARYING CONDITIONS

*Heat Sources.* The hourly Btu requirements of heating and cooling are not the only factors affecting summer–winter equipment balance of size, as defined by either compressor displacement or electrical demand. The third consideration is the source of heat and how far upwards in temperature the heat must be pumped which determines the maximum coefficient of performance of the unit. Heat sources, as already discussed, require further investigation.

At the lower heat source temperatures, it becomes necessary to use a larger refrigerant compressor displacement. In addition, an economical balance of equipment requires a larger evaporator to supply the needed heat at extreme low temperatures, as shown by Figure 6. This indicates clearly that the simple air-source heat pump will be limited to areas or applications where such extremes need not be contemplated.

*Modifying Effects of Storage.* However, only a smal percentage of the winter climate involves these extreme temperatures. It is also evident that these extremes seldom recur except at intervals of several weeks. This time spacing has been observed in a number of similar records of other geographical areas. Such conditions obviously suggest consideration of an air-source heat pump plus heat storage. By this expedient the heat pump may be sized for some milder temperature, to be determined from weather records and, ultimately, from experience. The equipment is assisted during peak loads by heat drawn from a storage tank.

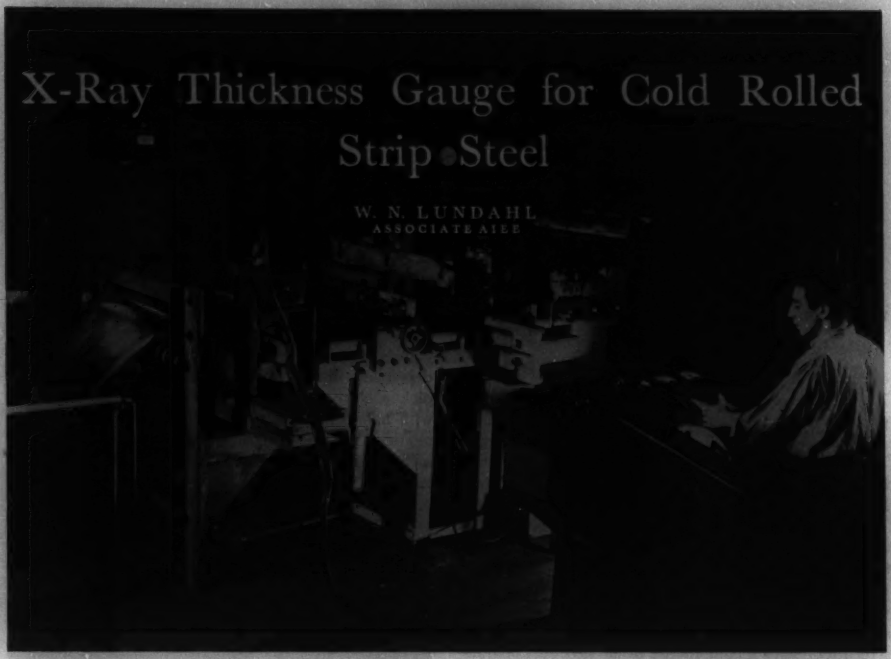
The air-source system with storage offers a higher load factor and a lower power demand than the well-water system. Required water storage at 200 degrees initial temperature is not excessive. For summer operation, in commercial buildings, full-load operating condition of any of these three systems (air, air and storage, well water) will cause electrical demand about equal to the winter demand of the well-water system.

Although for climates involving only occasional extreme temperatures, the addition of storage tends to keep the air-source heat pump in the running, for more severe climates very cold weather is so frequent that stored heat would be less effective in keeping down the size and maximum demand of heat pump equipment.

Heat storage not only is useful in restricting the electrical demand of an air-source heat pump but also may be put to another use. The demand from appliances in a residence may reach a high value for short periods. A heat pump without storage would have to operate to some extent during these hours, and its input would add directly to this peak. But with storage, the heat pump input can be reduced arbitrarily during this period, without disturbing the heat supply function.

# X-Ray Thickness Gauge for Cold Rolled Strip Steel

W. N. LUNDAHL
ASSOCIATE AIEE



**Design has been completed of an X-ray thickness gauge for cold mill and other applications utilizing one photoelectric multiplier pickup and two X-ray sources. The range of the gauge is 5 to 50 thousandths of an inch with accuracies up to one per cent.**

THE evolution of new and higher speed processes, new materials, and the trend toward greater precision and quality have necessitated development of more satisfactory gauging methods.

The combination of X ray and electronics lends itself admirably to many gauging problems. The outstanding advantage of this combination is that there is no physical contact between the gauge and the gauged material. Thus, it cannot scratch; there is little discrepancy due to paint and lacquer coatings; it is not subject to progressive shift in calibration from mechanical wear or through accumulation of scale or oxides picked up from the material; it enables continuous gauging of soft or thin material; limitations resulting from temperature theoretically do not exist; and satisfactory continuous high-speed gauging becomes practical as vibration and centrifugal force are not factors.

There are hundreds of applications for an X-ray thickness gauge. In addition to testing cold-rolled sheet steel, the gauge is well suited for the measurement of thickness of linoleum, plastic, sheet glass, many types of sheet metal, and paper and cardboard.

Basically, X-ray gauging is accomplished by irradiating the material under test and, in effect, measuring the drop in radiation intensity through that material. The heart of the X-ray thickness gauge is the pickup device which measures the transmitted radiation intensity quantitatively. Physical and chemical effects may be utilized as quantitative measurement of X-ray intensity with various degrees of practicability and success. Four such effects are heat content increase, photographic film exposure, gas ionization, and fluorescence.

The last effect was chosen for use in conjunction with a photoelectric multiplier. The envelope of the photo-

Essential substance of paper 48-14, "X-Ray Thickness Gauge for Cold Rolled Strip Steel," presented at the AIEE winter general meeting, Pittsburgh, Pa., January 26–30, 1948, and scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

**W. N. Lundahl** is a design engineer with the X-ray division of the Westinghouse Electric Corporation, Baltimore, Md.

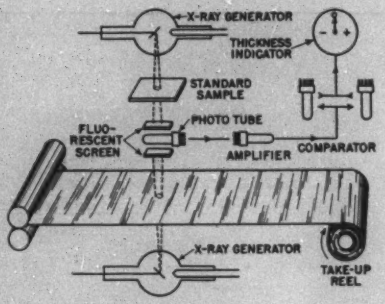



**Figure 1. Diagram of components of X-ray thickness gauge**

electric multiplier tube is surrounded with a sheet of X-ray fluorescent screen, and in turn covered by black paper or other covering to keep out extraneous light.

A fluorescent material absorbs photons of high energy. These high energy photons, which are absorbed by the fluorescent material, impart a portion of their energy in the form of lower energy photons (visible light). To obtain accurate response, it was determined that a "fast" screen is needed; that is, one with a high intensity but with very little afterglow. Also, the wave length of the visible light should be near that wave length to which the photoelectric tube is most sensitive. A Patterson-type *B* zinc-cadmium sulfide screen represents a compromise in the necessary characteristics.

The distance between the pickup and the X-ray source is important. The drop in intensity through air follows the inverse square law; thus, the intensity four inches away from the source would be one-fourth that of the intensity two inches away from the source. To keep the original intensity down to reasonable values for personnel safety and low X-ray tube loading, it is important that the pickup be kept near the source.

## BASIC GEOMETRICAL ARRANGEMENTS

Basically, all that need be involved is a single source of X radiation and pickup placed in such a position that it may receive the transmitted radiation emerging from the test material. Practically, however, this method allows cumulative errors to destroy any semblance of dependability and precision. Characteristic drifts in amplifier circuits and other allied apparatus, X-ray intensity changes resulting from voltage and current changes in the X-ray tube, and thermal effects all contribute toward large errors. Thus, it becomes necessary to utilize some comparison scheme where the signal obtained from the test piece may be compared with some standard signal, the complete unit having common parameters. Two sources of X rays and one pickup device are used for this as shown in Figure 1. In this instance both X-ray tubes are so arranged that their transmitted radiation after filtration from a master and a test piece, respectively, are applied to a single pickup device to enable subsequent electronic devices to differentiate between a standard signal and a test signal. The two X-ray tubes are so connected that they operate 180 degrees out of phase. Therefore pulses from each source arrive alternately at the common pickup.

The complete gauge consists of an X-ray source and pickup unit, a main control housing, a remote control panel, and an indicator unit.

The X-ray source consists of a self-contained oil-immersed X-ray generator. The X-ray tube, which operates self-rectified, has a tungsten target. The tube current is maintained at 0.5 milliampere and the tube voltage is varied between approximately 20 and 60 kv, depending upon the gauge of steel being run. The pickup device, which is the photoelectric multiplier with a fluorescent screen surrounding its envelope, is mounted in a brass housing located approximately two inches above the upper surface of the steel sheet. The standard X-ray source is located approximately ten inches horizontally from the photoelectric multiplier.

**Figure 2. Operator sliding sample into place in X-ray thickness gauge**

*From bottom up are shown the slide carriage that enables the gauge to move laterally across the strip, the lower X-ray head, the X-ray cone to confine the rays, two heavy guide plates through which the strip passes, the cylindrical X-ray pickup housing, and the standard sample. Behind the pickup is the upper X-ray head*

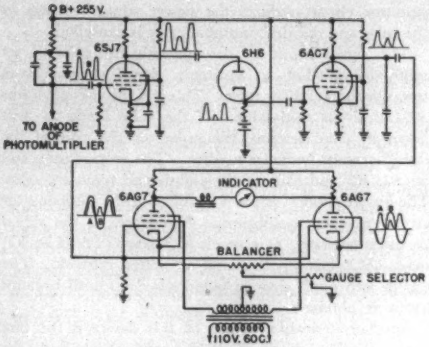



**Figure 3. Gauge circuit**

Its radiation is directed axially along a cylindrical brass X-ray cone through a standard sheet to the photoelectric multiplier. As shown in Figures 1 and 2, the other X-ray source is located beneath the test sheet. Its radiation is directed upward through the sheet to the photoelectric multiplier. The distances between the cathode of the photoelectric multiplier and the target of the two X-ray sources are equal. The photoelectric multiplier is so mounted that a projection of its sensitive surface bisects the right angle formed by the intersection of the radiation from the two heads. Because, in the cold mill application, X-ray source units and the pickup unit will be operating in an atmosphere with a heavy concentration of water vapor, oil, and scale, all electric connections are made waterproof.

The control housing may be mounted in any convenient location up to 150 feet or more from the pickup unit. Each basically distinct circuit is wired in a separate chassis. These chassis are mounted on a rack which swings away from the front panel to facilitate accessibility to the wiring. Interconnections between chassis are made with cable plugs to enable the serviceman to change quickly any particular unit that may need repair. These chassis contain the main gauge circuit and its power supply, a photoelectric multiplier power supply, a selective reject circuit, and a tandem milliampere stabilizer.

## THE GAUGE CIRCUIT

The gauge circuit (Figure 3) consists essentially of a pentode detector amplifier, a duplex diode clipper and base line restorer, a pentode saw-tooth converter, and a pair of power amplifier pentodes used in a comparator circuit. A pentode photoelectric multiplier stabilizer and a cathode ray indicator amplifier also are located in the gauge chassis.

The output signal obtained from the anode of the photoelectric multiplier is capacitor-coupled to a conventional stage of pentode amplification. The amplified signal from the first stage is coupled to the clipper section of the duplex diode where a portion of the signal is conducted through to the following stage. The percentage of the signal amplitude which is conducted depends upon the bias maintained across the tube elements. This stage serves two purposes. Sensitivity selection is obtained by varying the bias across the elements. As more of the lower portion the signal is clipped, the percentage amplitude differential between the standard pulse and the pulse representing instantaneous pass line thickness increases, thus increasing the thickness sensitivity. (Thickness sensitivity is defined as the percentage thickness differential between the standard sample and the instantaneous pass line thickness which will give a full scale thickness indicator deflection.) A second function of the diode is to prevent damaging currents from flowing through the indicator's movement in the event of large thickness differentials or complete removal of the pass line strip.

The cathode of the clipper is coupled to a pentode saw-tooth converter which in effect adds area to the pulses. The saw-tooth conversion is followed by the *6AG7* pair in a comparator circuit. This circuit operates in a somewhat unconventional manner. The control grids of the two tubes are in parallel. The cathodes are carried to ground through a potentiometer balancer and the gauge selector rheostat which is mounted in the

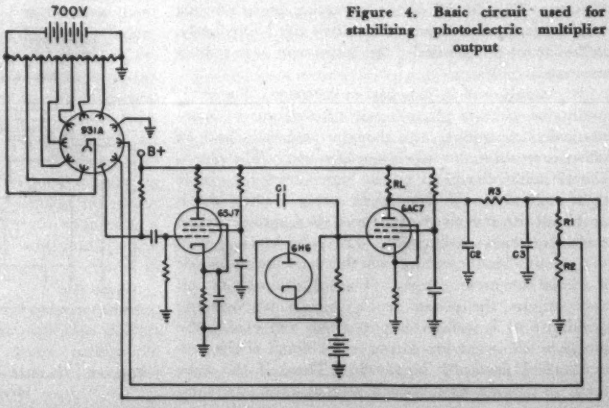



**Figure 4. Basic circuit used for stabilizing photoelectric multiplier output**

control panel. The plates are carried through identical load resistors to $B+$. The screen grids are connected to the opposite ends of the secondary of a transformer whose center tap is grounded. This circuit is, in effect, a bridge circuit in which the two plate load resistors and the two tubes act as the legs in the circuit. If a suitable instrument is placed between the two plates, any unbalance in the circuit will be indicated by a deflection proportional to the amount of unbalance. This indicating instrument is the instrument which indicates the thickness of the steel above or below the gauge of the standard piece. A high reactance choke is in series with the coils of the instrument to serve as a filter preventing alternating current from being applied to the movement.

The gauge as described is essentially a percentage reading device. However, the demands of industry are such that instruments of mensuration should not require conversion tables or conversion factors but must be of the direct reading type. There are certain circuit parameters which enable adjustment of sensitivity which subsequently could be used to obtain a direct reading instrument. The addition of a rheostat in the cathode circuit of the comparator provides a linear gauge selection control. Consequently, the operator may select the gauge of stock to be run by a simple adjustment of this calibrated rheostat at the remote control panel.

An electronically operated reject circuit operates from the output of the comparator circuit. The relays operated from this circuit close at predetermined thickness differentials for operation of reject mechanisms, alarm bells, or screw-down controls.

## THE PHOTOELECTRIC MULTIPLIER STABILIZER

It is well known that high vacuum photoelectric tubes employing the secondary emission principle such as the *931-A* which is used are subject to "drift" in their characteristics. This "drift" occurs in varying degrees during tube operation and over the tube's life. Obviously, drifts cannot be tolerated if the instrument is to remain accurate.

The circuit used in this particular gauge (Figure 4) maintains constant photoelectric tube output by automatically controlling the dynode potentials and in effect controlling the tube's amplification. The photoelectric multiplier picks up the signal from the visible light emitted by the fluorescent screen. The pulse is amplified throughout the tube and then applied to one stage of external amplification. This pulse then is applied to a circuit which determines whether or not the amplitude is within the preset range. This compensator circuit then adjusts the power supply of the photoelectric multiplier to a voltage output which will enable the photoelectric multiplier to put out a signal of the predetermined standard amplitude. Thus, if the tube tends to drift to an increased amplification, the compensator circuit reduces the power supply voltage to the tube and the drift automatically is cancelled.

The signal input to the photoelectric tube is set originally so that an optimum signal current flows through the stabilizer tube. This sets the voltage across *R1, R2* in its mid-value. If the tube tends to drift down in amplification, the pulse on the grid of the stabilizer tube becomes smaller. The voltage increases on *R1, R2,* and also on the eighth and ninth dynodes. The amplification increases again until the compensator circuit reaches equilibrium. Conversely, if the signal becomes too large as a result of a positive drift in *T1,* more voltage is "peeled" off the filter network. The eighth and ninth dynode potentials drop until balance again is obtained.

Another desirable feature of this device is the fact that complete removal of the test sheet and the consequent subjection of high intensity radiation directly upon the pickup device does not injure the photoelectric multiplier. The instant the test sheet is removed, the stabilizer automatically drops the eighth and ninth dynode potentials to a value low enough to prevent damaging currents from flowing.

## SELECTING X-RAY INTENSITY

The X-ray source will be operating continuously, and thus the rating of the X-ray tube, which is generally the weakest link, must not be exceeded. The intensity of the X-ray beam is directly proportional to the current flowing in the X-ray tube and approximately proportional to the square of the voltage across the elements of that tube. Thus, to keep the losses down, it is possible to operate the tube at a very low current and obtain the intensity necessary for correct excitation of the photoelectric multiplier by voltage adjustment. In the cold mill gauge, the X-ray tubes are operated at a

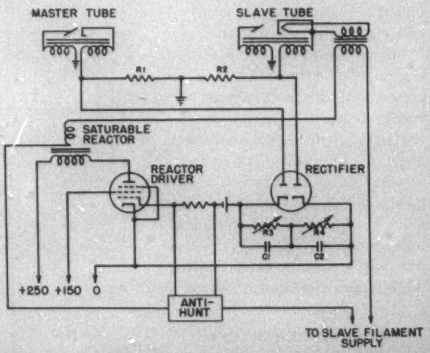



**Figure 5. Tandem milliampere stabilizer used for maintaining identical X-ray tube currents**

constant current of one-half milliampere, with tube voltages varying from 20 to 60 kv dependent upon the gauge of the material being run.

Although extensive theoretical calculations indicate that for any given thickness of a certain material, there is one optimum voltage for attainment of maximum sensitivity with monochromatic X rays, calculations corroborated by experiment clearly have shown that voltage is not a highly critical factor in thickness gauge sensitivity because of the wave length distribution as integrated over one pulse of radiation. Thus, voltage selection for a given gauge of material involves only two factors: obtaining a satisfactory optimum photoelectric multiplier output, and setting the photoelectric multiplier stabilizer in the midpoint of its range.

### THE TANDEM MILLIAMPERE STABILIZER

Operating the X-ray sources without any means of stabilization results in undependable gauge indication. X-ray tube current is dependent upon filament temperature which is quite likely to vary. It is therefore necessary to maintain, automatically, identical current magnitudes at all times. This is accomplished with a tandem milliampere stabilizer. This electronic device maintains current equality by using current through one tube as reference and having the current of the other tube follow the former.

The stability is obtained by comparing the two currents and using the voltages produced in the comparison to bias a control tube which varies the magnitude of a series reactance in the filament power supply of the "slave" tube.

An antihunt device using a feed-back transformer and a duplex diode rectifier, capacitor-coupled to the grid circuit, prevents oscillation because of high sensitivity and quick response to small current changes.

The entire X-ray generator is stabilized by an induction regulator. Voltage applied to the X-ray tubes must be equalized carefully to obtain coincident intensities of the resultant heterogeneous radiation. The variation in inherent filtration of the X-ray generators themselves because of slight differences in X-ray tube window thickness, oil surrounding the tube, and head window thickness result in slight deviations from equality with equal increments of voltage change on the two X-ray tubes. Therefore, with changes of thickness of stock to be run, which require changes in tube voltage, slight rebalancing is usually necessary. With matched heads, these changes are so slight that a small X-ray current adjustment satisfactorily will correct output intensities with no adverse effects to accuracy.

The addition of a solenoid-operated slide mechanism, which inserts a preselected gauge of stock into the test beam, enables quick checks on gauge calibration. This device is mounted directly above the test sheet head.

### PERSONNEL PROTECTION

In the cold-mill gauge, there is no way possible for the operating personnel to be exposed directly to the primary radiation. The only danger that might exist is from the refracted and reflected X rays or scatter. The direct radiation is of an entensity low enough that the scatter radiation two inches from the point of the test sheet being irradiated is of an intensity much lower than the maximum dosage rate as given by the American Standards Association. In a hot-mill gauge, where the steel thicknesses are sometimes more than a quarter of an inch, and the X-ray source-to-test sheet distance must be quite large because of the temperature of the sheet, the intensity of scatter will be proportionately greater. However utilization of proper protective means will eliminate any danger. The X-ray thickness gauge as in any X-ray application must utilize personnel protection proportional to the power of the generating unit involved.

## Automatic Chemical Analysis

For years spectrochemical methods of analysis have been used for metals. A specimen is vaporized by an electric current, and the light from the glowing gaseous metal is broken up into a spectrum and photographed. The intensity of characteristic colors or lines indicates how much of a given constituent is present. Though such methods are quicker than chemical analysis, they involve photographic development, as well as density measurements and calculations. These analyses require 20 minutes or longer and require highly trained personnel.

The February 1948 issue of the *Industrial Bulletin* of Arthur D. Little, Inc., Cambridge, Mass., reports that direct-reading spectrometers now are being produced that complete analysis of a specimen containing about a dozen elements in approximately two minutes. The intensity of spectral lines is measured with photoelectric tubes, and the results appear directly on tapes or dials. The machine is complicated and expensive, costing from $20,000 to $50,000 or more, with its associated equipment in an air-conditioned room. Setting one up for a given type of alloy requires a trained installation crew. Once set up, the equipment must be adjusted to a standard several times each day. However, it can be operated by personnel with only a few days' training. Where large numbers of similar alloys must be analyzed, the machine can save much of the cost of an analytical laboratory.

The bulletin goes on to say that in several large companies this instrument is an established part of production control. As each batch of alloy is prepared, a sample is poured into a small mold and sent to the laboratory through pneumatic tubes. There an analysis of the material is available in about 30 seconds.

# Electrochemical Sources of Electric Power—I

GEORGE W. VINAL
FELLOW AIEE

**Prompted by current interest in the possibilities of atomic energy, *ELECTRICAL ENGINEERING* is presenting a series of articles reviewing the various known and tried methods of producing electric power in the light of present-day knowledge. Previously published articles reviewed electric power sources in general, piezoelectricity, and electrostatic power sources.* The present article considers another source, the battery, or electrochemical source of power, and will appear in two parts. Part 1 presents an historical résumé of the subject, while part 2 will describe its technical aspects.**

ENERGY in its various forms is familiar to all. We know it by the work that it does. The heat energy of live steam, the mechanical energy of a motor, the chemical energy of reacting substances are manifestations of energy. The public has become acutely conscious within the past few years of the mightiest source of energy—atomic fission. Electric energy derived from electrochemical reactions is the immediate subject, but it is related so intimately to heat and chemical phenomena that they too must engage our attention. One form of energy is transformed into another. Joule[1] established the mechanical equivalent of heat by a series of experiments between 1840 and 1843. Gaston Planté[2] (1834–1889) who gave to the world the first practicable storage battery at the age of 26, reported 13 years later charging his battery by electromechanical means. He employed a Gramme generator driven by a hand-operated crank. How long this process took we do not know, but when the battery was charged and cranking stopped, the machine operated as a motor on current supplied by the battery. The cycle of transformations then was completed: mechanical energy to electric energy to chemical energy and back to electric energy and mechanical energy. Batteries do not store electricity as such. The chemical energy of the reacting constituents in the individual cells is the source of electricity supplied by the battery when it is discharged. How precisely chemical energy is converted into its equivalent electric energy and the converse will be discussed in part 2 of this article.

## THE BEGINNING OF ELECTRICITY

From the seventh century B.C. when Thales observed that amber would attract light objects, if rubbed, to the close of the 18th century A.D., knowledge of electricity accumulated slowly. Gilbert (1540–1603) is said to have been the first to use the word "electricity." Static electricity was the source of many sensational and sometimes uncontrolled experiments. The advent of the Leyden jar in the middle of the 18th century permitted the actual storage of electricity, as these jars are condensers or, as we should say now, capacitors. Groups of such jars were called "batteries," but they did not generate electricity. "Battery" is a word of many uses. It conveys the idea of a group of like units acting together and thus we speak of a battery of guns, of boilers, of cells, or the pitcher and catcher of a baseball team.

Three years before Franklin[3] made his famous kite experiment in 1752, he wrote to his friend, Peter Collinson of London:

> Chagrinned a little that we have hitherto been able to produce nothing in this way of use to mankind; and the hot weather coming on when electrical experiments are not so agreeable, it is proposed to put an end to them for this season, somewhat humorously, in a party of pleasure on the banks of the Skuylkil.

A turkey was killed by electric shock and toasts were drunk in electrified bumpers which nipped the unwary.

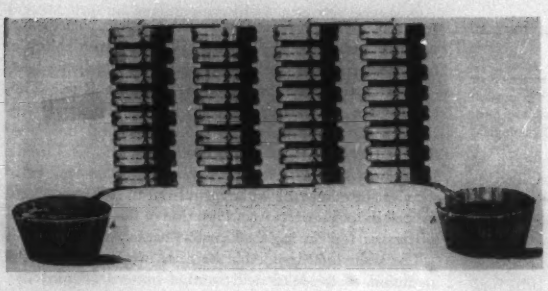
A new era of electrical experimentation began in 1800 when Alessandro Volta[4] (1745–1827), who was professor of natural philosophy in the University of Pavia, communicated his epoch-making discovery of the voltaic pile (Figure 1) and crown of cups to the Royal Society of London in a letter addressed to the Right Honorable Sir Joseph Banks. Volta's "letter" amounting to 28 printed pages described in detail his experiments. He knew that the effects produced were greater when he employed a larger number of couples and he mentioned making the pile as high as would sustain itself without falling down. He built his pile of silver, brass, or copper against tin, or zinc, but mentions repeatedly that silver and zinc was the best combination. Between adjacent pairs of dissimilar metals he placed layers of pasteboard ("carton") or animal's hide or other porous materials well soaked in water or other fluid which may be a better conductor. The crown of cups was described in the same letter. It is perhaps less famous, but Volta evidently regarded it as a more effective source of electricity because it did not

---

Part 1 of a 2-part article comprising essentially full text of a conference paper presented at the AIEE Midwest general meeting, Chicago, Ill., November 3–7, 1947.

George W. Vinal is chief of the electrochemistry section, division of electricity and optics, National Bureau of Standards, Washington, D. C.

* The following articles have been published in *ELECTRICAL ENGINEERING* on the subject of electric power sources: "Electrostatic Sources of Electric Power," by John G. Trump (*EE, Jun '47, pp 525–34*); "Nature and Use of Piezoelectricity," by W. G. Cady (*EE, Aug '47, pp 758–62*); and "Electric Power Sources," by E. W. Mutsch and Wilbur C. Brown (*EE, Sept '47, pp 880–1*).



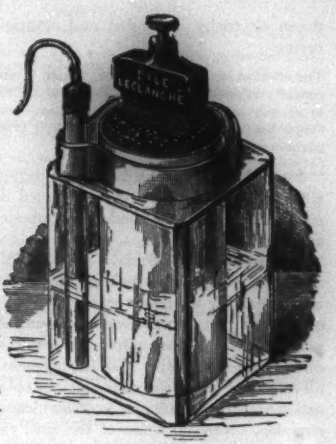



**Figure 1 (above). Volta's pile**

**Figure 3 (right). Leclanché's cell**

fail as a result of dryness. Volta's contribution far outmoded the earlier methods of producing electricity because it afforded for many succeeding years the only practical means for producing electricity in considerable and manageable quantities.

Volta's announcement of his pile and crown of cups came at a time when the world was ready and waiting for a new and better source of electric energy. The effect of his letter in England was immediate. Within six weeks of the time Volta dispatched his letter, Nicholson and Carlisle[5] constructed a pile of silver half-crowns and disks of zinc and with this accomplished the electrolytic decomposition of water. A few years later Sir Humphrey Davy successfully decomposed the "fixed alkalis" and saw the first metallic potassium. Davy built large batteries, and in 1809 with a battery of 2,000 couples demonstrated the "full splendors of the electric arch" (arc).

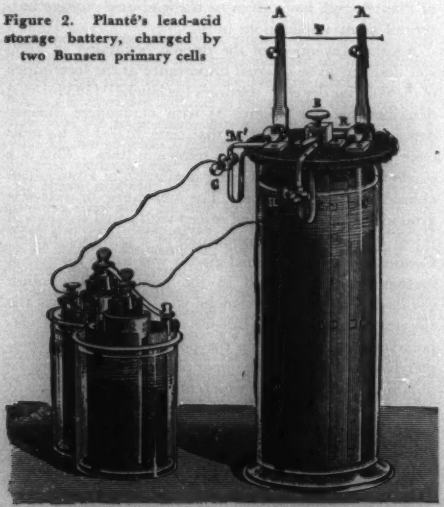



**Figure 2. Planté's lead-acid storage battery, charged by two Bunsen primary cells**

## EARLY BATTERIES

While these notable experiments held the attention of the scientific public, less was said of the batteries which made them possible. Volta's pile had limitations. Increase in size meant increase in weight and the conducting liquid was squeezed out. The crown of cups occupied much space. It is not surprising therefore to find the early experimenters seeking different arrangements. Cruickshank soldered zinc and copper plates back-to-back to form what we now would call duplex electrodes. These were spaced in a trough and the space between plates was filled with the "exciting liquid." Leakage, local action, and polarization were troublesome. Filling the battery was tedious and discouraging because the best activity of the first-filled cells was spent before filling the last of the cells could be completed. This difficulty led to plunge batteries of various types and sizes, so arranged that the plates could be lifted out of the solution when not required for use.

Electricity from various sources was not regarded as identical in its nature until Faraday's third series of experimental researches: "Ordinary" electricity was obtained by rubbing together certain materials. Volta added electricity from batteries. Thermoelectricity, derived by heating the junction of dissimilar metals, was discovered by Seebeck. Animal electricity was manifested by the shock received from electric fishes. To these Faraday added the most important of them all, electricity generated by electromagnetic induction in 1831. In this he realized his "hope of obtaining electricity from ordinary magnetism."

By applying eight different tests Faraday reached the important conclusion that electricity, whatever its source, is identical in its nature. Faraday distinguished be-

tween electricity in tension and electricity in motion, saying:

> The effect of electricity of tension, at rest, is either attraction or repulsion at sensible distances. The effect of electricity in motion or electric current may be considered as: first, heat; second, magnetism; third, chemical decomposition; fourth, physiological phenomena; fifth, spark.

In 1833 Faraday[8] discovered his well-known laws of electrochemical action and later coined the words electrode, electrolyte, ions, anode, and cathode, which are in common use today.

Notwithstanding Faraday's discovery of a new source of electric energy, batteries continued to be the principal instrumentality for many years. During the first third of the 19th century they were not essentially different in principle from Volta's pile or crown of cups although differing in size, shape, and arrangement. They were all subject to the detrimental effects of polarization, local action and the necessity for frequent cleaning and reconstruction. Amalgamation of the zinc, variously attributed to Kemp and Sturgeon about 1836, materially helped to decrease local action.

Polarization largely was overcome by the advent of 2-fluid cells. John Frederick Daniell[9] described the famous cell which bears his name in 1836, although the principle was anticipated by Antoine Becquerel[8] several years earlier. Daniell's "constant" cell employed the hollow gullet of an ox as the means of separating the dilute solution of sulphuric acid in which a zinc rod was immersed from the saturated solution of copper sulphate surrounding a copper cylinder. Not long afterward Daniell replaced the gullet by a porous cup and otherwise improved the cell.

The principle involved in Daniell's cell led to many modifications. One of these is known as the "gravity cell," occasionally seen at the present time. This is essentially a closed circuit cell, as a small continuous current is needed to maintain a sharp meniscus between the dense copper sulphate solution and the less dense solution of zinc sulphate above it.

## LATER INVENTIONS

Only a few of the more important cells that were invented during the following quarter of a century can be mentioned. The Grove cell[9] in 1839 consisted of a platinum electrode in nitric acid and zinc in a solution of hydrochloric or sulphuric acid. Like Grove's cell, but substituting carbon for platinum, Bunsen's cell [10] of 1842 became important. At about the same time Benjamin Silliman[11] constructed a similar battery at Yale University in which he used natural plumbago, not knowing at the time of Bunsen's use of carbon. Smee's cell of 1840 employed platinized platinum and zinc in a solution of sulphuric acid. It was used for open circuit applications and later was modified by substituting platinized silver or platinized carbon as less expensive materials.

Other cells of the middle 19th century included the mercury cell of Marie-Davy and Gaiffe's battery for medical induction apparatus. Various silver chloride batteries appeared during this period of which the best known is probably that of Warren De la Rue. The bichromate cell is attributed to Johann Poggendorf.[12] It has points of similarity to the Bunsen cell, but only one fluid, a bichromate solution in sulphuric acid, was used. In its best known form, the Grenet or bottle-type cell, the electrodes may be withdrawn from the solution when the cell is not in use. An adaptation of this was used as a miltary battery during the Franco-Prussian war in 1871.

The year 1860 is notable because of Gaston Planté's invention of the lead acid storage battery (Figure 2). Born in 1834, he gave to the world the first practical storage battery without reserving to himself the rights that might have been his under patent protection. His book "Researches on Electricity"[13] begins with a discussion of voltaic polarization and the production of secondary currents. These had been discovered at the beginning of the century, but the succeeding 50 years had not sufficed to reconcile conflicting opinions about secondary currents. Planté sought to utilize the effects of polarization as a means of storing the electric energy of primary batteries. In 1860 he devised "a secondary element of great intensity" by rolling together sheets of lead with separation between. The electrolyte was ten per cent sulphuric acid. We cannot but admire Planté's patience in forming and charging these plates when primary batteries were, at the time, the only source of current. Improvements in design, the process of pasting the active materials into grids invented by Faure in France and Brush in the United States, the development of wood and rubber separators, all combined with the basic principles of Planté's cell, have given us the lead-acid storage battery of many applications today.

Another invention of the decade beginning in 1860 was destined to be of great importance as the forerunner of the familiar dry cell. Georges Leclanché[14] (1839–1882) described his cell (Figure 3) with manganese dioxide depolarizer in 1868, but at that time 20,000 of his cells were in use on railroads and telegraph lines. This is a single fluid primary cell using a solution of ammonium chloride as the electrolyte. The manganese dioxide was ground rather coarsely and mixed with equal volumes of retort carbon. It was contained in a porous cylinder. Connection to the external circuit was made through a carbon plate embedded in the mixture. The other electrode was zinc. Leclanché was particular that the electrolyte only should half-fill the jar so that the depolarizing mixture within the porous jar was not completely wet, at least in the upper portion. By so doing he obtained a better output which may have been the result of some atmospheric depolarization. Air had been found to have some depolarizing action as far back as Wollaston's trough battery of 1815.

In 1876 Leclanché described a modification of his cell. The depolarizing mix with the addition of a binder was

pressed into an agglomerate block and the porous cup was no longer necessary. Shortly before 1890 there was great activity in the production of modified cells with the primary object of making the electrolyte unspillable. Gassner's cell most closely resembled the modern dry cell although the depolarizer and electrolyte differed.

### THE ELECTRODE

Copper and zinc electrodes which had been used since the time of Volta were found in many early types of cells but with the advent of solid depolarizers in the form of oxides, led by Planté and Leclanché, it was to be expected that the insoluble black oxide of copper would find its place in batteries. Lalande[15] patented such a cell in 1881. It was the copper oxide-zinc-caustic soda type subsequently modified by Edison and known and used today as the railway signal primary cell.

Shortly after the turn of the century Edison invented the nickel-iron alkaline storage battery and about the same time Jungner in Europe developed the nickel-cadmium type of alkaline storage battery. Intensive research as a part of war activities have produced several new types to be mentioned in the second part of this article. Some of these for military use are not well adapted to civilian needs.

### REFERENCES


1. **J. P. Joule.** *Philosophical Transactions* (London, England), 1850, page 61.

2. Sur une Experience d'Electrodynamique, **Gaston Planté, A. Niaudet.** *Comptes Rendus* (Paris, France), volume 76, 1873, page 1259.

3. A Century of Electricity (book), **T. C. Mendenhall.** 1890, page 9.

4. On the Electricity Excited by the Mere Contact of Conducting Substances of Different Kinds, **Alessandro Volta.** *Philosophical Transactions* (London, England), volume 90, 1800, page 403 (in French).

5. Magnetism, Electricity, and Electromagnetism up to the Time of the Crowning Work of Michael Faraday in 1831, **J. J. Fahie.** *Journal*, Institution of Electrical Engineers (London, England), volume 69, 1931, page 1331.

6. Experimental Researches, **Michael Faraday.** Series 3, 1833, paragraphs 377 and 505.

7. On Voltaic Combinations, **John Frederick Daniell.** *Philosophical Magazine* (London, England), series 3, volume 8, 1836, page 421.

8. **Antoine Becquerel.** *Annales des Chimie et Physique* (Paris, France), volume 41, 1829, page 22.

9. **William R. Grove.** *Philosophical Magazine* (London, England), series 3, 1839, Volume 14, page 388; volume 15, page 287.

10. **Robert Wilhelm Bunsen.** *Poggendorff's Annalen der Physik und Chemie* (Leipzig, Germany), 1842, volume 54, page 417; volume 55, page 265.

11. **Benjamin Silliman.** *American Journal of Science* (New Haven, Conn.), 1842, volume 43, page 393; volume 44, page 180.

12. **Johann Poggendorf.** *Poggendorff's Annalen der Physik und Chemie* (Leipzig, Germany), volume 57, 1842, page 110.

13. Recherches sur l'Électricité (book), **Gaston Planté,** Gauthier-Villars, Paris, France, 1883.

14. **Georges Leclanché.** *Les Mondes*(Paris, France), volume 16, 1868, page 532.

15. **F. P. E. de Lalande.** *Electrotechnische Zeitschrift* (Berlin, Germany), volume 5, 1884, page 233.


# A Magnetic Recorder for Power Systems

From Armour Research Foundation in Chicago, Ill., comes word of a proposed magnetic recorder with a "memory" for use on power systems. The incoming signal is to be recorded continuously on an endless loop of magnetic material, and each element of the material is erased just prior to its passage over the recording head. When a system disturbance is recognized, the recording head and the erase head can be de-energized. Such a recorder can provide a record of system operation for a specified interval prior to occurrence of a disturbance.

It seems probable that the initiation of the recorder function well may be tied to the alarm bus with an adjustable time-delay relay so that the record retained might include, for example, five seconds before and ten seconds after the alarm.

On playback, voltages essentially identical to those recorded would be delivered to output terminals. These voltages then are available for delivery to an orthodox photographic Duddell oscillograph, or to a cathode-ray oscilloscope, or to a standard laboratory indicating instrument. The last device would permit the rms value to be obtained directly. The recording can be played back an indefinite number of times without essential loss of quality of the recording. While the function of the playback might be separated from that of the recording, present thinking is in the direction of including both functions in the same unit.

In considering the technical requirements for a recorder, two considerations seem to be important. They are certain system voltages and currents, and the operational sequence of relay and circuit breaker functions. For the voltages and currents, accuracy comparable to that of indicating instruments is desirable and frequency response up to the fifth harmonic is of value. For the channels recording sequential operation, a much larger amplitude error is permissible. A recorder having the following characteristics is suggested:

| | |
|---|---|
| Total number of recording channels | 20 |
| Number of high-accuracy channels | 5 |
| Number of low-accuracy channels | 15 |
| Time duration | 15 seconds |
| Power supply | 125 volts (direct current) |
| Upper frequency limit (high-accuracy channels) | 300 cycles |
| Upper frequency limit (low-accuracy channels) | 1,000 cycles |
| Error, high-accuracy channels | less than plus or minus 2 per cent |
| Error, low-accuracy channels | approximately plus or minus 20 per cent |

The five high-accuracy channels would include frequency modulation using a carrier frequency of 1,000 cycles per second.

# Report on Industrial Voltage Requirements

AN AIEE COMMITTEE REPORT

THIS REPORT is published to bring its contents to the attention of a larger group of interested engineers than were contacted through its presentation at general meeting sessions so that a broader understanding will be obtained and a wider experience brought into the picture. The suggestions given are the recommendations of the committee, are not to be interpreted as AIEE Standards, and are in no way mandatory. Comments or suggestions by the readers will be appreciated and considered by the committee. Such comments also will be considered for publication as "Letters to the Editor," and may be addressed to Professor Clyde C. Whipple, 85 Livingston Street, Brooklyn 2, N. Y.

Among the objectives of the report are

1. To show the importance of the proper utilization voltage to the satisfactory operation of industrial electric apparatus.

2. To ascertain and to analyze prevailing operating conditions of industrial plants with particular reference to utilization voltages.

3. To scrutinize the elements of industrial distribution systems and to suggest a reasonable allocation of the voltage drops between incoming line terminals and the terminals of the utilization devices.

4. To recommend voltage spreads at terminals of utilization devices under normal operating conditions.

5. To recommend preferred voltage ratings and taps for industrial power transformers.

6. To outline voltage zones and voltage spreads at the supply or service entrance of the industrial user's plants which will meet the foregoing objectives.

7. To promote consideration by an appropriate joint Edison Electric Institute–National Electrical Manufacturers Association–AIEE committee of the problem stated in objective 6, with a view to the ultimate adoption of suitable recommendations as to preferred supply voltage zones and spreads.

The scope has been limited in several ways.

1. This report applies only to those industrial plants receiving power at primary voltage, that is, at 2,400 volts or higher, or generating their own power at 2,400 volts or higher. It does not apply to industrial plants receiving power at 600 volts or lower.

2. No recommendations are made herein concerning the preferred voltage ratings of utilization devices, although it is recognized there are inconsistencies in existing ratings of such devices.

3. Most of the recommendations made in this report are limited to those elements of the distribution system over which the plant engineer may exercise control, one exception being in connection with the preferred voltage ratings and taps of industrial power transformers.

## Basic Principles of Industrial Voltage Distribution

### EXPLANATION OF TERMS

*Nominal Voltage.* The nominal voltage of a circuit, or system, is a value assigned to a circuit, or system of a given voltage class, for the purpose of convenient designation.

The choice of the specific value to represent nominal system voltage is purely arbitrary; however, it should have as much practical meaning as possible. In general, it is believed that it should represent somewhere near the average of voltage existing on a particular voltage class of systems. For example, 460 volts has been chosen as the nominal voltage of one system voltage class (Table I). The value 480 volts, the standard transformer rating used to supply this class of system, or 440 volts, the motor rating, could have been chosen. However, in present-day practice the average voltage is not as high as 480 volts or as low as 440 volts; hence, 460 volts, a more representative value, has been chosen. In other instances, particularly in higher voltage systems where there is generally little voltage drop, the nominal system voltage has been chosen to be the same as the transformer ratings, that is, 2,400 volts in the nominal voltage ratings of a class of systems generally supplied by transformers rated 2,400 volts.

Essentially full text of paper 47-157, "Report on Industrial Voltage Requirements," presented at the AIEE summer general meeting, Montreal, Quebec, Canada, June 9–13, 1947.

This report was prepared by the subcommittee on industrial voltage requirements of the AIEE committee on industrial power applications. The personnel of the subcommittee was **C. C. Whipple** (M '26, *chairman*) professor and chairman of undergraduate electrical engineering department, Polytechnic Institute of Brooklyn, Brooklyn, N. Y.; **H. G. Barnett** (M '41) central station engineer, Westinghouse Electric Corporation, East Pittsburgh, Pa.; **C. A. Johnson** (M '13) Westinghouse Electric International Company, New York, N. Y.; **C. R. Johnson** (A '37) electrical engineer, United States Rubber Company, New York, N. Y.; **L. C. Peterman** (M '44) electrical engineer, Ford, Bacon and Davis, Inc., New York, N. Y.; **R. C. R. Schulze**, American Gas and Electric Service Corporation, New York, N. Y.; **H. Speight** (M '21) industrial engineer, Westinghouse Electric Corporation, New York N. Y.; **W. H. Dickinson** (M '43) engineer, general engineering department, Standard Oil Development Company, Elizabeth, N. J.; **D. L. Beeman** (M '43) engineer, industrial engineering divisions, General Electric Company, Schenectady, N. Y.; **J. Grotsinger** (M '44) manager, electrical engineering division, Goodyear Tire and Rubber Company, Akron, Ohio; **S. F. French** (M '39) electrical engineer, Anaconda Copper Mining Company, New York, N. Y.; **K. Pinder** (F '45) senior electrical engineer, E. I. du Pont de Nemours and Company, Wilmington, Del.; **T. O. Sweatt** (M '44) electrical engineer, Wearn, Vreeland, Carlson, and Sweatt, New York, N. Y.; and **S. A. Warner** (M '30) assistant distribution engineer, electrical engineering department, Consolidated Edison Company of New York, Inc., New York, N. Y.

The committee acknowledges and appreciates the co-operation of the joint Edison Electric Institute–National Electrical Manufacturers Association committee on preferred voltage ratings for a-c systems and equipment, and the joint EEI–NEMA committee on transformers. Through their co-operation several points of disagreement were eliminated, and a better understanding of each other's problems was provided. Where differences in recommendations still exist, it is hoped that through further discussion with the appropriate committees involved, these differences may be reconciled.

**This subject matter has been the basis for a series of conference sessions, beginning at the 1946 AIEE winter general meeting. Additional discussion and comments by the readers are invited and may be addressed to Professor Clyde C. Whipple, 85 Livingston Street, Brooklyn 2, N. Y.**

*Rated Voltage.* The rated voltage is the voltage to which operating performance characteristics of apparatus and equipment are referred.

*Voltage Spread.* Voltage spread is the difference between maximum and minimum voltages existing in any one voltage class system under specified steady-state conditions. Voltage spread is not intended to cover momentary voltage changes of a transitory nature such as those due to switching surges, motor starting, and welders.

This report primarily is concerned with voltage spread at utilization equipment, which is the difference between the maximum and minimum voltage at the terminals of utilization equipment at *all locations* in a particular plant at *all times* under normal system operating conditions (Figure 1). Maximum values usually appear during light load and minimum values at full load on the electric system.

Another important type of voltage spread is primary or supply voltage spread, which is the difference between the maximum and the minimum voltage at the service entrance of a particular plant, at all times under normal operating conditions.

*Voltage Zone.* A voltage zone is the envelope of all voltage spreads for a particular voltage class system in a specified area.

For any specific voltage class, designated by a nominal system voltage, there inherently exists an appreciable range of operating voltages between the systems having the highest voltage and the systems having the lowest voltage for that class. Countrywide this zone is larger than the voltage spread at any one location because of recognized differences in practices of different companies.

For example, in the nominally 2,400-volt class of systems, one company might operate with an average of 2,400 volts with a small variation because of voltage regulation. Another company might operate with average voltage of 2,200 volts. Primary voltage zones are the only zones referred to in this report. These are intended to cover differences in operating practices.

Specific primary voltage zones referred to in this report are the maximum to minimum voltages that are expected to be encountered. The zones refer to the voltage at the service entrances or plant generating busses.

*Transformer Voltage Rating.* Transformer voltage ratings are *always* the no-load voltage ratings. The ratio of primary to secondary voltage rating is the same as the primary to secondary turn ratio.

If a transformer is rated 2,400 to 480 volts, with 2,400 volts impressed on the primary, 480 volts will appear at the secondary terminals at no load. If exactly 2,400 volts is maintained at the primary terminals and load applied to the secondary terminals, the voltage at the secondary terminals will drop below 480 volts. The magnitude of the drop will depend upon the transformer impedance, and the magnitude and power factor of the load connected to the secondary terminals. For these reasons, the secondary voltage under load (except for

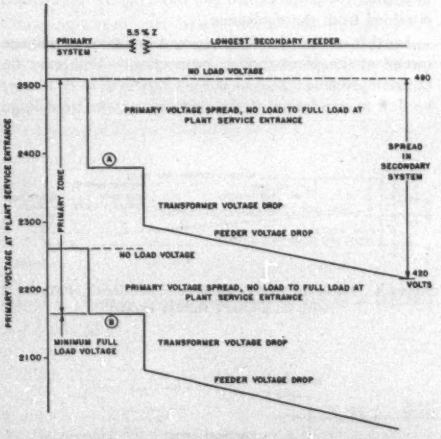



**Figure 1. Examples of voltage zones, spreads and drops considered**

*A—Transformer operating on highest tap ratio 2,520 to 480 volts at no load*

*B—Transformer operating on lowest tap ratio 2,260 to 480 volts at no load*

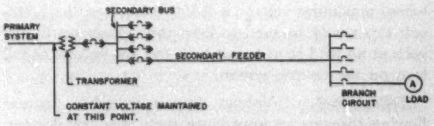



**Figure 2. Typical industrial plant power circuit**

*Constant primary voltage assumed*

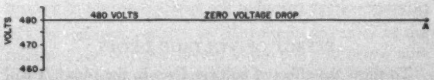



**Figure 3. No-load voltage conditions for circuit of Figure 2**

**Table I. Recommended Voltage Spread at the Terminals of Utilization Devices in 600-Volt and Below Industrial Distribution Systems**

| Nominal System Voltage | Commonly Used Utilization Device Voltage Ratings | Recommended Limits of Voltage at Terminals of Utilization Devices |
|---|---|---|
| 120 to 208Y-connected | 115 or 120 1-phase<br>208 or 220 3-phase | *197Y-connected, to 114–217Y-connected, to 125 |
| 230 | 220†, 230 | 210–240 |
| 460 | 440†, 460 | 420–480 |
| 575 | 550†, 575 | 525–600 |

Designations for nominal system voltages are those commonly used in industrial plants.

* Polyphase power loads may not operate satisfactorily at this lower limit.

† These are standard polyphase motor voltage ratings.

leading power factor loads) always will be less than the secondary voltage at no load for a given primary voltage.

*Transformer Taps.* Nearly all standard transformers in the ratings 100 kva and above have taps in the windings to change the turn ratio. The taps do not affect materially the voltage drop through the transformer; they merely change the turn ratio; hence, the no-load voltage rating. For example, a standard transformer rated 2,400 to 480 volts may have four $2^1/_2$-per-cent taps in the 2,400-volt winding. In present ratings of transformers for industrial systems, the taps usually are placed two above and two below rating. If the taps are so located, the transformer may be adjusted to give any of the following no-load ratios:

2,520 to 480 volts—five per cent above
2,460 to 480 volts—$2^1/_2$ per cent above
2,400 to 480 volts—normal rating
2,340 to 480 volts—$2^1/_2$ per cent below
2,280 to 480 volts—five per cent below

These taps are not for improving voltage regulation but only for changing the general voltage level in the plant. If a 2,400-to-480-volt transformer is connected to a system whose maximum voltage is 2,520 volts, then the tap 2,520 to 480 volts would be used to give about 480 volts at no load on the transformer (Figure 1). However should the transformer be connected to a system whose maximum voltage is 2,300 volts, then the 2,340-volt tap would be used to keep the voltage up to 480 volts at no load so as to not have too low voltage at full load on the electric system.

*Voltage Drop.* Voltage drop is caused by current flowing through an impedance such as a transformer, cable, reactor, or bus.

Voltage drop in the power system within the industrial plant is the cause of part of the difference in voltage in various parts of a power system. The other cause is primary voltage spread at the service entrance of a plant.

## EFFECT OF VOLTAGE DROPS

To show the effect of voltage drop in the plant, it will be assumed that the primary supply voltage is maintained at a constant value regardless of plant load. A simple circuit, shown in Figure 2, will be used as an illustration. The primary voltage is assumed to be of such magnitude that the secondary voltage on the transformer is 480 volts at no load. Referring to Figure 3, at no load, no current flows; hence, there is no voltage drop through the transformer or in any of the secondary circuits connected to the transformer. Consequently, the voltage is substantially the same throughout the plant and any lights or other incidental load connected at this time is subjected to practically the no-load voltage.

When load is connected to the transformer, current flows and this causes a voltage drop in the secondary circuits as shown in Figure 4. At the secondary bus, the voltage drop, caused by current flowing through the transformer, is 15 volts. Hence, with constant primary voltage the voltage at the secondary bus varies from 480 volts at no load to 465 volts at full load—the voltage spread at this point is 15 volts. There are assumed additional drops of 10 volts in the secondary feeder and 5 volts in the branch circuit making a total drop to load *A* of 30 volts. If the lowest voltage in the plant exists at load *A* then the voltage spread is 480 at no load to 450 volts at full load or 30 volts.

In designing an industrial power system, the voltage spread should be kept at a minimum consistent with reasonable first cost. If the spread is too great, the voltage may be too high at light loads, causing burn out of equipment operating during that period; or the voltage may be too low at full load at much of the utilization apparatus, impairing the performance and reducing the production obtained from the equipment.

Another cause of voltage spread is primary voltage spread at the plant service connection. This may be caused by voltage drop in the primary system or it may be due to regulation of the primary system by voltage

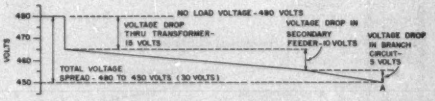

480
470
460
450
VOLTS
NO LOAD VOLTAGE - 480 VOLTS
VOLTAGE DROP THRU TRANSFORMER - 15 VOLTS
VOLTAGE DROP IN SECONDARY FEEDER - 10 VOLTS
VOLTAGE DROP IN BRANCH CIRCUIT - 5 VOLTS
TOTAL VOLTAGE SPREAD - 480 TO 450 VOLTS (30 VOLTS)
A

**Figure 4. Full-load voltage conditions for circuit of Figure 2 with no primary voltage spread**

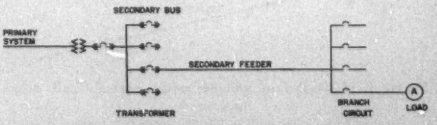



**Figure 5. Typical industrial plant power circuit**

*Primary voltage spread assumed in this example*

regulators. To show the effect of primary voltage variation, assume that the primary voltage drops as load comes on in the plant. The simple circuit of Figure 5 will be used, in which the transformer, secondary feeder, and branch circuit voltage drops are the same as in Figure 2 and Figure 4.

With reference to Figure 6, the transformer taps have been selected so that the no-load voltage is 480 volts. When load comes on the power system, the same voltage drops occur as in Figure 4, but in addition the primary system voltage is assumed to drop sufficiently to cause a 10-volt drop in voltage at the secondary terminals of the transformer. This primary voltage spread adds to the total voltage spread in the plant, making the spread 480 to 440 volts, or a total of 40 volts, as shown in Figure 7, instead of only 30 volts, as in Figure 4 where there was no primary voltage variation.

The primary voltage spread may not be always in the direction shown in Figure 7. The primary voltage may rise as load comes on the plant because of voltage regulators in the primary feeder circuit or other voltage regulators in the primary power system. This voltage rise on the primary reduces the voltage spread in the plant as shown in Figure 8.

Very weak primary systems with a high drop, or regulated primary system whose load cycle does not coincide with the load cycle of the plant, may cause excessive voltage spread in the plant, beyond the limits shown in Table I. This is illustrated in Figure 9. Automatic voltage regulation is required in such instances to bring the voltage spread within the limits shown in Table I. Changing transformer taps to increase the voltage at full load will not solve the problem because that will increase the no-load voltage beyond 480 volts as shown in Figure 10. A change of taps merely shifts the existing voltage up but does not reduce the voltage spread as can be seen by comparing Figure 9 and Figure 10.

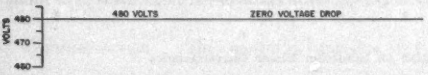



**Figure 6. No-load voltage conditions for circuit of Figure 5**

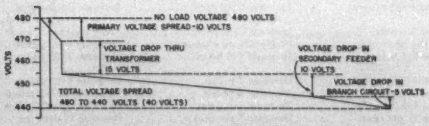



**Figure 7. Full-load voltage conditions for circuit of Figure 5**

*Ten volts (on 460-volt basis) primary voltage spread down from maximum primary voltage at no load to minimum primary voltage at full load*

**Table II. Example of Tables I and VII Applied to a 460-Volt System Supplied From a 2,400-Volt System**

| Item | Volts |
|---|---|
| 1. Transformer secondary no-load voltage, with supply voltage at maximum and with no load on transformer | 468*–480† |
| 2. Full-load voltage at terminals of farthest devices with supply voltage at a minimum and with full load on transformer | 420–432 |
| 3. Total voltage spread (difference between items 1 and 2) | 48 |
| 4. Assumed allocation of voltage spread of item 3, suggested as reasonable values applying in the majority of cases | |
| Voltage spread in primary supply (460-volt base) | 20 |
| Voltage drop through transformer | 15 |
| Voltage drop in secondary wiring | 13 |
| 5. Zone of primary supply voltage | 2,130–2,520 |

Note: The exact allocation of voltage spreads indicated is not as important as keeping the total voltage spread within the values of item 3.

* This value occurs when supply voltage is at most adverse location between taps, that is, when it is slightly higher than the voltage rating of the next lower tap setting.

† This value is the maximum desired under maximum conditions, occurring when supply voltage is optimum with respect to taps, and is the same as the voltage rating of the tap setting.

## EFFECT OF VOLTAGE SPREAD ON UTILIZATION EQUIPMENT

*General Effects.* Whenever the voltage at the terminals of a utilization device varies from the name plate rating of the device something is sacrificed either in life or performance of the equipment. The effect may be minor or serious depending upon the characteristics of the devices, how it is applied, and the amount the voltage deviates from the device rating. NEMA standards provide certain tolerances which may be taken advantage of without seriously effecting the performance of the apparatus. However, with wide usage of electric power for precise operations, there is often a major sacrifice in production for voltage variations of considerably less than given in the NEMA standards pertaining to a specific piece of equipment.

So that plant engineers better can judge the effect of voltage variation on the electric equipment in their plant, the characteristics of many commonly used devices are given here. It is these characteristics which have been used as the starting point for establishing the desired voltage spread of Tables I and II.

*Induction Motors.* Motors are the most common utilization device in industrial plants. The variation in characteristics as a function of voltage for the widely used induction motors are shown in Figure 11 and in Table III.

*Principal Effects of Low Voltage on Induction Motors.* The most significant effects of too low voltage are reduction in starting torque and increased full load temperature rise. The reduction of starting torque may be significant in motor applications driving high inertia equipment; the lower torque will result in longer acceleration periods. Torque motors also are affected materially by reduced voltage, as the torque decreases as the square of the voltage; hence, at ten per cent below normal voltage the torque is reduced 19 per cent.

The increased heating at low voltage and full load

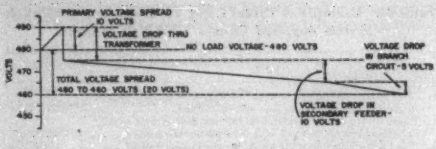



**Figure 8. Full-load voltage conditions for circuit of Figure 5**

*Ten volts (460-volt) primary voltage spread up from minimum primary voltage at no load to maximum primary voltage at full load*

reduces the life of the insulation. Overload capacity is reduced about 19 per cent.

*Principal Effects of High Voltage on Induction Motors.* The most significant effects of too high voltage are increased torque, increased starting current, and decreased power factor.

The increased torque may cause couplings to shear off or damage to driven equipment. Increased starting current causes greater voltage drop in the power system, hence, increased light flicker. Decreased power factor is particularly disadvantageous where power factor penalty clauses are applied by the utilities. The higher the motor voltage rises, the lower the power factor will become; this may result in a greater penalty, and, hence, a higher power bill.

Although the temperature rise at full load on standard motors decreases slightly for moderate overvoltages, the temperature rise may increase on certain types of special motors at even very small overvoltages. Overvoltages of the order of 10 to 15 per cent have caused numerous burn outs on special 4-speed grinder motors. Motors rated for intermittent load also are affected materially by overvoltages.

Although many drive applications are not seriously affected by voltage deviations as much as plus or minus ten per cent from rated voltage, there are important applications that are. The problem of an important manufacturer of laundry machinery is a good example. This company produces washers of the revolving drum type that rotate from seven to nine revolutions forward and then seven to nine revolutions in reverse, from three to six reversals per minute. The load is an overhauling load and the motor must have an extremely low starting and plugging torque to prevent shock on reversal and damage to the machine. However, the motor must have sufficient starting torque to insure proper acceleration. Experience has shown that a variation in torque of more than plus or minus ten per cent from rating will cause operating difficulties. This calls for a voltage that must remain constant within five per cent. If number of reversals is not held accurately, clothes will be twisted and are hard to remove.

The same manufacturer also produces extractors of the centrifugal type. An extractor requires a comparatively high torque and is not reversible. Torque variations must be held within small limits. Excess torque causes too rapid acceleration and results in poor distribution of the load and unbalanced operation, and presents a definite operating hazard. The peripheral speed is $1^1/_2$ miles per minute and an unbalance means vibration and ultimate damage. Low torque, on the other hand, lengthens the accelerating time, reduces the extracting ability of the machine, and causes overheating of the equipment.

What makes this problem more serious is that the laundry equipment referred to enjoys very wide use in all parts of the United States and, therefore, is operated under the full variety of voltage conditions that exist at the present time.

*Synchronous Motors.* The effect of voltage variation on the performance of synchronous motors is similar to that on induction motors. However, although the starting torque varies as the square of the voltage, the maximum or pull-out torque varies directly with the voltage.

It will be noted from these discussions that, in general, voltages slightly in excess of the motor name plate rating

**Table III. General Effect of Voltage Variation on Induction Motor Characteristics**

| Characteristic | Function of Voltage | 90 Per Cent Voltage | 110 Per Cent Voltage | 120 Per Cent Voltage |
|---|---|---|---|---|
| Starting and maximum running torque | (Voltage)$^2$ | Decrease 19 per cent | Increase 21 per cent | Increase 44 per cent |
| Synchronous speed | Constant | No change | No change | No change |
| Per cent slip | 1/(Voltage)$^2$ | Increase 23 per cent | Decrease 17 per cent | Decrease 30 per cent |
| Full load speed | (Syn speed − slip) | Decrease $1^1/_2$ per cent | Increase 1 per cent | Increase 1.5 per cent |
| Efficiency | | | | |
| Full load | | Decrease 2 points | Increase $^1/_2$–1 point | Small increase |
| $^3/_4$ load | | Practically no change | Practically no change | Decrease $^1/_2$–2 points |
| $^1/_2$ load | | Increase 1–2 points | Decrease 1–2 points | Decrease 7–20 points |
| Power factor | | | | |
| Full load | | Increase 1 point | Decrease 3 points | Decrease 5–15 points |
| $^3/_4$ load | | Increase 2–3 points | Decrease 4 points | Decrease 10–30 points |
| $^1/_2$ load | | Increase 4–5 points | Decrease 5–6 points | Decrease 15–40 points |
| Full load current | | Increase 11 per cent | Decrease 7 per cent | Decrease 11 per cent |
| Starting current | Voltage | Decrease 10–12 per cent | Increase 10–12 per cent | Increase 25 per cent |
| Temperature rise, full load | | Increase 6–7 C | Decrease 3–4 C | Decrease 5–6 C |
| Maximum overload capacity | (Voltage)$^2$ | Decrease 19 per cent | Increase 21 per cent | Increase 44 per cent |
| Magnetic noise, no load in particular | | Decrease slightly | Increase slightly | Noticeable increase |

Note: This table shows general effects, which will vary somewhat for specific ratings.

**Table IV. Effect of Voltage Variations on Incandescent Lamp Characteristics**

| Indicated Voltage | Per Cent Rated Voltage | Per Cent Rated Light Output | Per Cent Theoretical Life* |
|---|---|---|---|
| 99.6 | 80 | 48.6 | 1907 |
| 104.3 | 85 | 58.5 | 832 |
| 108.0 | 90 | 70.0 | 398 |
| 110.4 | 92 | 75.4 | 298 |
| 112.8 | 94 | 81.1 | 225 |
| 115.2 | 96 | 87.2 | 171 |
| 117.6 | 98 | 93.3 | 130 |
| 120.0 | 100 | 100 | 100 |
| 122.4 | 102 | 107 | 77 |
| 124.8 | 104 | 114 | 60 |
| 127.2 | 106 | 122 | 47 |
| 129.4 | 108 | 130 | 36 |
| 132.0 | 110 | 138 | 29 |
| 138.0 | 115 | 163 | 16 |
| 144.0 | 120 | 190 | 9 |

* Theoretical life in absence of any mechanical breakage. In ordinary service mechanical breakage reduces the life expectancy at the lower voltages.

have less detrimental effect on motor performance than voltages below the motor name plate rating. This is the basis on which the voltage spreads of Table I were determined. As an example, the figures show a recommended spread of 420 to 480 volts for the 460-volt nominal system voltage, which is approximately four per cent below and nine per cent above the 440-volt motor rating.

*Incandescent Lamps.* The light output and life of incandescent filament lamps are affected critically by the impressed voltage. In Table IV this relationship is shown for a voltage range from 80 to 120 per cent of rated voltage.

In general, it may be said that for incandescent filament lamps a 1-per-cent deviation from rated voltage causes a change of 3 to 3.5 per cent in the light output. It can be seen from Table IV that a 10-per-cent reduction in lamp voltage results in 30-per-cent reduction in light output. In other words, when the voltage is 10 per cent low, the investment in the lighting system is working at only 70 per cent efficiency—hence 30 per cent of the investment is lost. With an overvoltage of 10 per cent the lamp life is reduced to less than one-third—hence lamp replacement costs are tree times as great as at normal voltage.

*Fluorescent Lamps.* The changes in lamp characteristics with variation in circuit voltage are given in Figure 12 and Table V. In general, 1-per-cent variation in line voltage will change the lumen output only about one per cent. Voltage is a factor in starting reliability and voltages lower than recommended may result in unsatisfactory starting.

It will be noted that the over-all efficiency of fluorescent lamps decreases as the line voltage is raised above normal. The increased line voltage causes the choke to pass more current to the lamp. This lowers the resistance of the arc column resulting in a lower voltage drop across the lamp itself. The input watts to the lamp are increased slightly and, therefore, the lumen output increases over a certain range. In this condition, however, the higher current density produces the short ultraviolet radiation less efficiently; consequently, the luminous efficiency of the lamp decreases.

Fluorescent lamps are, however, less vulnerable to voltage variations than incandescent lamps.

*Resistance Heating Devices.* The energy input and, therefore, the heat output of resistance heaters varies, in general, with the square of the impressed voltage. Thus, a 10-per-cent drop in voltage will cause a drop of 19 per cent in heat output. This, however, holds true only for an operating range over which the resistance remains constant.

Many heating devices are designed conservatively and, if thermostatically controlled, will operate satisfactorily even if the voltage varies ten per cent or more.

However, in many instances, the designer must confine his heating units in a minimum of space and, therefore, must operate them near maximum rating. Also, the temperature requirements for many heating applications require the operation of the heating units at maximum temperature. A drop in voltage means a drop in heat input varying with the square of the voltage, and a loss in production. On the other hand, excessive voltage will increase the temperature of the heating units and, therefore, will reduce their life. This condition applies especially to furnaces operating at high temperatures, temperatures near the maximum permissible for the type of heating unit used. To assure uniform high production

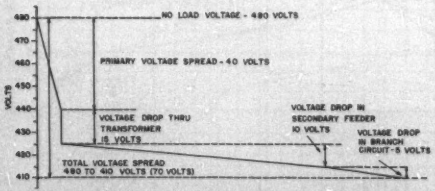



**Figure 9. Full-load voltage conditions for circuit of Figure 5**

*Large primary spread (40 volts on 460-volt basis). Primary voltage drops from maximum at no load to minimum at full load*

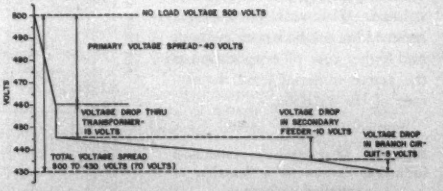



**Figure 10. Full-load voltage conditions for circuit of Figure 5**

*Same conditions as in Figure 9 except that transformer is operating on tap to give higher secondary voltage*

and the best operating conditions, the voltage should be maintained within a spread of plus or minus five per cent of rated voltage.

*Infrared Heating Processes.* Although the filaments in the lamps used in these installations are of the resistance type, the energy output does not vary with the square of the voltage, because the resistance varies at the same time. The radiated energy of these lamps is nearly proportional to the wattage input for a voltage range of 50 to 150 per cent of rated voltage.

The watts input and radiant energy of these lamps is related to the socket voltage as shown in Figure 13 for a lamp rated 120 volts.

Although the change in wattage and radiated energy is only 7 per cent for a 5-per-cent change in voltage, this change can be more harmful to the user than a larger change in a typical resistance heater. In this instance, the device is not thermostatically controlled, so that a change in voltage causes a change in temperature, adversely affecting production. If the voltage is subnormal, the conveyer speed must be reduced and lower production results. If excessive, the speed must be increased to avoid burning the product.

Therefore, it can be concluded that infrared heating processes are among the operations which critically are affected by voltage changes.

*Electronic Equipment.* The current-carrying ability or "emission" of all electronic tubes is affected seriously by voltage deviation from rating. Figure 14 shows typical emission curves plotted against cathode heater voltage. Curve 1 applies to most of the thyratrons, pliotrons, and receiving tubes. Curve 2 applies to the small transmitter tubes and some of the battery-heated tubes. Curve 3 applies to the oscillator tubes such as used in high-frequency induction and dielectric heaters.

The cathode life curve indicates that the life is reduced by half for each 5-per-cent rise in cathode voltage. This results from both reduced life on the heater element and higher rate of evaporation of the active material from the surface of the cathode.

The factor of reduced cathode life with higher voltage needs no explanation. However, at voltages below rating, the loss of emission has very serious secondary effects. In a vacuum tube, such as the pliotron and kenotron, a small loss of emission below that needed means reduced output and sometimes excessive tube heating, which is reflected in a shorter life. However, for gas-filled tubes, such as thyratrons and phanotrons, in which the current is not limited by the tube-space charge, if insufficient emission is available to carry the load current, the gas molecules bombard the cathode surface and may destroy it quickly, wrecking the tube in a matter of minutes. Therefore, it is extremely important that the cathode voltage be kept up near rating on these tubes for satisfactory service.

In addition to these factors, there are other important things to be taken in consideration. If the voltage is too high, the evaporated material from the cathode may contaminate the grid or anode causing grid current and arc back, making the tube inoperative.

If the cathode voltage is too low in a gas-filled tube, the surface cannot be activated properly and loses its emitting efficiency very quickly. This permits bombardment, as explained, and destruction of the cathode.

It can be seen that it is more serious to permit the voltage to fall below rating than to be slightly above. Standard industrial tubes are designed to operate with a voltage tolerance of plus or minus five per cent. However, if a closer tolerance than this can be obtained, the user

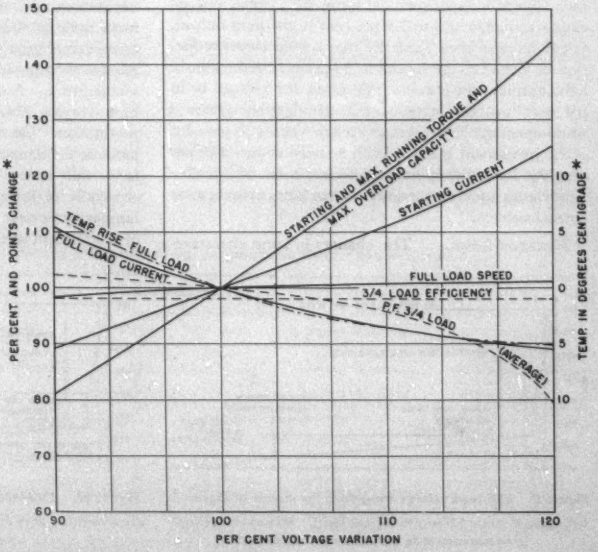



**Figure 11. Characteristics of standard induction motors as a function of applied voltage**

——— *Per cent change*
– – – – *Points change*
– – – – *Temperature change*

amply will be repaid in increased tube life and reliable operation. If voltage swings must be tolerated, it is more desirable that the minimum swing be to not less than 95 per cent of rating, even though the average voltage must be held slightly above rating. This practice, of course, will give somewhat reduced tube life, but it will prevent the rapid deterioration which can be caused by too low voltage, and so is to be preferred.

Though the effect of voltage change is most important on the tube cathode, it is also undesirable in the other parts of the circuit.

Electronic circuits, as all other electric circuits, lose power capacity rapidly if the voltage is decreased from rating. Although critical circuits normally contain voltage regulator tubes and other means to hold a constant reference voltage in spite of line voltage variations, economic reasons prevent voltage regulation on the majority of circuits and hence their function will be impaired by excessive voltage variation. This is especially true when magnetic saturation is part of the control function.

*Solenoid-Operated Devices.* In this group fall solenoids, brakes, valves, and clutches. The pull of a-c solenoids varies approximately as the square of the voltage. There is some deviation from this law, depending on the part of the *B–H* curve on which the solenoid is working. The temperature rise, too, varies approximately as the square of the voltage.

In general, solenoids are designed liberally and standard commercial solenoids are designed to operate satisfactorily on 10 per cent overvoltage and 15 per cent undervoltage. Because an a-c solenoid has an inrush current of approximately ten times the sustained value when sealed, the branch circuit supplying it should be of ample capacity to prevent an excessive voltage drop.

**Table V. Effect of Voltage Variations on Fluorescent Lamp Characteristics**

| | Per Cent of Rated Voltage | | | | |
|---|---|---|---|---|---|
| | 90 | 95 | 100 | 105 | 110 |
| Per cent lumens | 85 | 94 | 100 | 107 | 112 |
| Per cent life | 80 | 90 | 100 | 90 | 80 |

*Capacitors.* The corrective ability of capacitors varies with the square of the impressed voltage. A drop of 10 per cent in the supply voltage, therefore, reduces the corrective ability by almost 20 per cent, and where the user has made a sizable investment in capacitors for power factor correction, he loses the benefit of 20 per cent of this investment.

## Recommended Voltage Spread for Industrial Power Applications

### RESULTS OF SURVEYS

Preceding the 1946 AIEE winter general meeting, it was agreed to conduct a field survey of limited extent to poll industrial engineers on their ideas regarding permissible spread in utilization voltage. The results of this first poll agreed very closely with the tentative recommendations made by the industrial power applications committee in its interim report. Nevertheless, after the meeting it was decided to make a much more extended survey so as to cover a much broader field and to include industrial sections all over the United States. In Figures 15 through 20, results of these polls are summarized.

To obtain the desired information, a questionnaire was prepared, the purpose of which was to

1. Obtain information on the actual voltage spread now being experienced over a wide section of the country.

2. Obtain the opinion of qualified industrial users on the recommended and permissible voltage spreads for lighting and industrial power applications.

The form of the questionnaire was given considerable thought. It finally was decided to request information on

1. Recommended and permissible limits of voltage for lighting, motor, heating, welding, and miscellaneous loads.

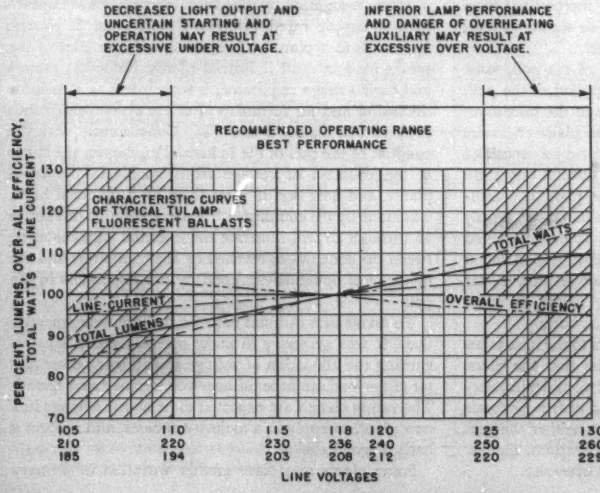

DECREASED LIGHT OUTPUT AND UNCERTAIN STARTING AND OPERATION MAY RESULT AT EXCESSIVE UNDER VOLTAGE.
INFERIOR LAMP PERFORMANCE AND DANGER OF OVERHEATING AUXILIARY MAY RESULT AT EXCESSIVE OVER VOLTAGE.
RECOMMENDED OPERATING RANGE BEST PERFORMANCE
CHARACTERISTIC CURVES OF TYPICAL TULAMP FLUORESCENT BALLASTS
TOTAL WATTS
LINE CURRENT
OVERALL EFFICIENCY
TOTAL LUMENS
PER CENT LUMENS, OVER-ALL EFFICIENCY, TOTAL WATTS & LINE CURRENT
130
120
110
100
90
80
70
105 110 115 118 120 125 130
210 220 230 236 240 250 260
185 194 203 208 212 220 229
LINE VOLTAGES

**Figure 12. Characteristics of fluorescent lamps as function of voltage applied to ballast**

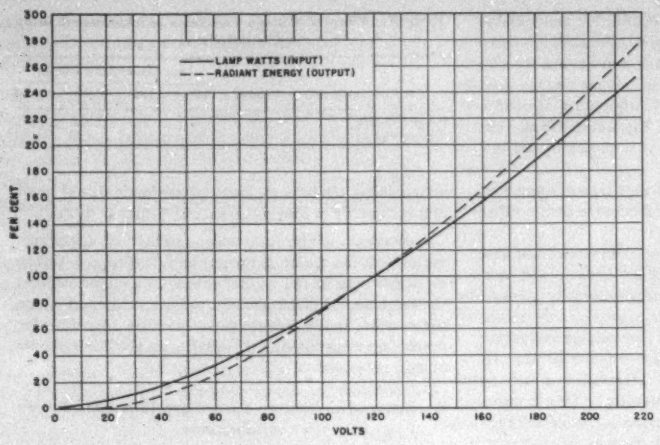



**Figure 13. Characteristic data of drying lamp**

*General Electric Company 250-watt 20-volt R-40 drying lamp. Radiant energy measured on the axis of the lamp with an open-type thermopile at a test distance of three feet*

2. The voltage spread, existing under normal operating conditions, within the plant at

(a) The service entrance of power supply.
(b) The terminals of the load devices.

3. The average load in the plant being reported.

The questionnaires were sent to a list of 450 engineers, selected on the basis of their qualification to express an opinion, of which approximately 25 per cent were returned properly filled out.

In evaluating the results of the poll, it proved to be extremely difficult to resolve the results into weighted averages, so that they could be presented in the form of a tabulation. Consequently, the graph method has been employed, as all of the results can be so shown without introducing errors from extreme values.

To understand properly the results of the poll, some explanation appears necessary. As applied to the poll, the term "recommended limits" refers to the maximum and minimum voltage limits that the plant engineers recommended should be maintained on a specified industrial distribution system during normal operation of the plant. Normal operation of the plant is considered to be plant operation with all of the power supply facilities in service and with plant load at least one-third of average load. Light load operation occurs when plant load is less than one-third of average load, as, for example, week-end operaion of many plants, or when the plant is partially shut down for some reason.

"Permissible limits," in the poll, refers to the maximum and minimum allowable voltage limits that the plant engineers would permit or would not consider intolerable, for light load operation, or during heavy overloads and shutdowns. It is to be noted that neither the poll nor this report considers emergency operations, that is, when part of the supply facilities are out of service.

Shown in Figures 15 through 18 are the poll results of the recommended voltage for lighting loads and of the recommended and permissible voltages for three voltage classes of motors: 220, 440, and 2,200 volts. The latter is referred to 2,200 volts as this has been the name plate voltage of the majority of motors in this class. Superimposed on the poll graphs will be found the recommended voltage limits shown in Tables I and VI, representing the recommendations of this committee.

In Figures 19*A* and 20*A* are shown, respectively, the reported voltage spreads of the power supply and at the loads. The magnitude of the average loads of the plants reported are shown in Figures 19*B* and 20*B*. Because of the great variety of voltages reported, it was found convenient to convert the data to a percentage base to conserve space.

## RECOMMENDED VOLTAGE SPREAD AT UTILIZATION EQUIPMENT

It was recognized by the committee that it was impractical to supply rated voltage to each piece of electric apparatus in a plant. Comprising a major part of the power load in most industrial plants, induction motors and their voltage requirements were taken as a basis for discussion and for formulation of the recommendations presented in Tables I and VI. Concurrently with the conduct of the poll of the industrial engineers, the study of the problem of voltage requirements in industrial plants, and how best to meet them on a practical basis, was made by the committee. An examination of Figures 15 through 20 will illustrate the essential agreement between the conclusions reached by the committee and the majority of opinions expressed by the responders to the poll.

To arrive at a rational basis for making recommendations, it was necessary to make several assumptions regarding the allocation of voltage spread, the power factor of the load, and the primary voltage zone and spread. The values chosen are expected to be about average in a new plant, to apply in a majority of cases, and to form a basis of good design.

Some plants may have greater variation in primary

**Table VI. Recommended Voltage Spread at the Terminals of Motors Served at Primary Voltage**

| Nominal System Voltage | Motor Name Plate Voltage Rating | Recommended Limits of Voltage at Terminals of High-Voltage Motors | |
|---|---|---|---|
| | | Min (−2 Per Cent) | Max (+8 Per Cent Approx) |
| 2,400 | 2,200 | 2,160 | 2,380 |
| 2,400 | 2,300* | 2,250 | 2,480 |
| 4,160 | 4,000 | 3,920 | 4,320 |
| 4,800 | 4,600 | 4,500 | 5,000 |
| 6,900 | 6,600 | 6,470 | 7,130 |

* Present standard motor voltage rating.

supply, in which instance voltage regulators or power factor improvement may be required to reduce the voltage spread. In other cases, the combination of these values may be such that a large secondary feeder drop or a larger primary voltage spread could be encountered and not go beyond the limits of Table I. However, the values given in combination with the primary voltage zones of Table VII may occur without requiring voltage regulation or power factor improvement and yet meet the limits of Table I with the transformer ratios which have been recommended in Table VIII. This allows for those instances in which the primary voltage encountered falls between the tap ratings of the transformers at the most adverse point.

For 230, 460, and 575-volt industrial distribution systems, primarily for power loads, the following assumptions are made:

1. The primary voltage spread, based on nominal system voltage for that voltage class, is approximately 4 per cent, or 20 volts on a 460-volt system.

2. The voltage drop through the transformer under load, based on an 85-per-cent power factor, is about 3.2 per cent or 15 volts on a 460-volt system.

3. The maximum secondary feeder drop is about 2.8 per cent or 13 volts on a 460-volt system.

4. The primary voltage zone is approximately nominal system voltages plus 5 to minus 11 per cent.

For 120-volt or Y-connected 208 to 120-volt industrial distribution systems, used primarily or largely for lighting loads, the following assumptions are made:

5. The primary voltage spread is the same as in assumption 1 if transformer is supplied at 2,400 volts or higher. It is about 7 per cent or 8 volts on a 120-volt base, if the transformer is supplied at 600 volts or below.

6. The voltage drop through the transformer under load is about 1.5 per cent or 2 volts on a 120-volt base, based on a unity power factor load.

7. The maximum secondary wiring drop is about 2.5 per cent, or 3 volts on a 120-volt base.

8. The primary voltage zone is the same as in assumption 4, if the transformer is supplied at 2,400 volts or higher. It is approximately plus 3.3 to minus 5.7 per cent, if the transformer is supplied at 600 volts or below.

Tables I and VI show recommended voltage spreads at terminals of devices in industrial plants. In Table II an example is given of these recommendations as applied to a 460-volt system supplied from a 2,400-volt system. In Table IX a similar example is given in connection with these recommendations as applied to a 120-volt system supplied from a 460-volt system having a voltage spread as recommended herein.

## Voltage Ratings and Taps for Industrial Power Transformers

### THE PROBLEM

The selection of transformer ratios and taps for industrial applications is based essentially on three factors

1. Desired voltage spread at utilization equipment.
2. Primary voltage zone to be covered.
3. Voltage drops and primary voltage spread.

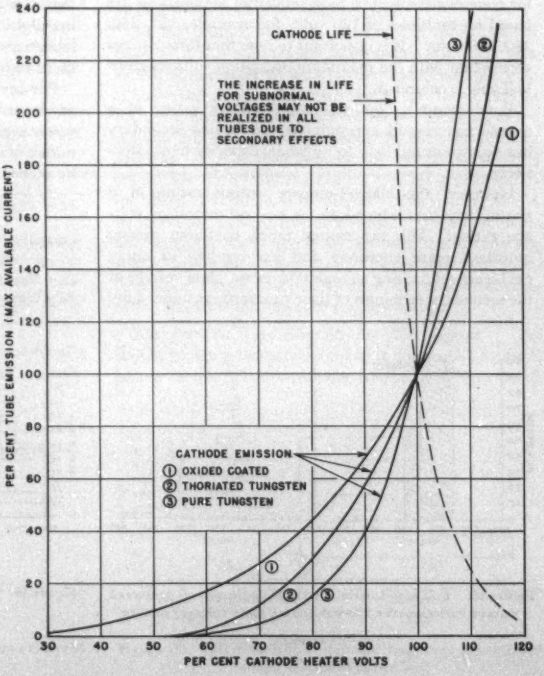



**Figure 14. Electronic tube emission and life versus the voltage of the cathode**

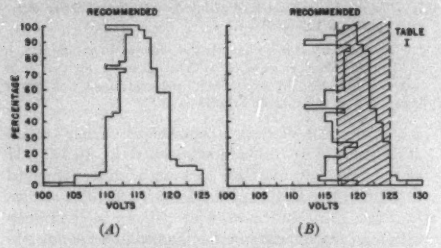



**Figure 15. Poll of industrial electrical engineers of preferred voltage variations recommended for lighting**

*A—Lighting name plate voltage of 115 volts*
*B—Lighting name plate voltage of 120 volts*

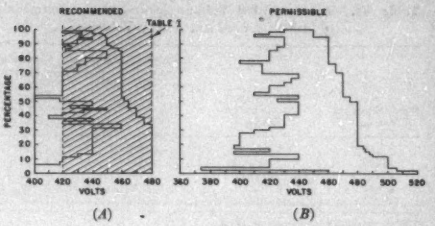



**Figure 17. Poll of industrial electrical engineers on preferred voltage variations for 440-volt motors**

*A—Recommended*
*B—Permissible*

These factors have been discussed fully and are summarized in Tables I, VI, and VII.

## CONSIDERATIONS INFLUENCING APPLICATION OF TRANSFORMERS

By definition, the primary and secondary voltage ratings of power transformers are based on no-load, or open circuit, conditions. Present EEI–NEMA voltage ratings for transformers used in most industrial applications are based on multiples of 120 volts, for example, 120, 240, 480, 600 volts. It is important to note that these ratings correspond with the maximum utilization voltages given in Table I, column 3.

Fundamentally, the secondary voltage rating of a transformer should approximate the desired secondary bus voltage at full load to utilize its capacity most effectively.

However, the kilovolt-ampere output rating of a transformer now is based on the no-load secondary voltage rating. This has caused much confusion among industrial plant engineers and has resulted in many engineers attempting to maintain name plate voltage at the secondary terminals of their transformers under fully loaded conditions without realizing that the no-load voltage then would be considerably higher than is desirable or safe for the utilization equipment. In general, the full-load voltage should correspond with the nominal system voltage given in Table I, column 1.

The problem of selecting transformer voltage ratings and taps is influenced by two major operating conditions. First, that of maintaining secondary voltages within safe limits for proper operation of utilization equipment during light loads. Second, that of obtaining sufficient secondary voltage during full load conditions for equipment remote from the transformer.

For any one particular condition the secondary voltage at terminals of utilization equipment that would result when a given primary voltage is impressed on the terminals of a transformer approximately may be calculated by means of the following formula.

$$SE \approx (PE \times SR/PR) - (TD + FD)$$

where,

$SE$ = Secondary voltage at utilization equipment
$PE$ = Primary applied voltage

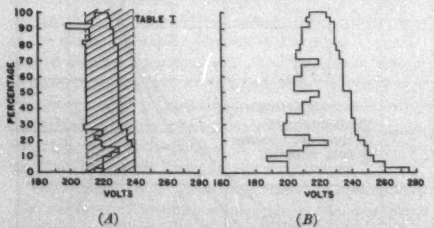



**Figure 16. Poll of industrial electrical engineers on preferred voltage variations for 220-volt (name plate voltage) motors**

*A—Recommended*
*B—Permissible*

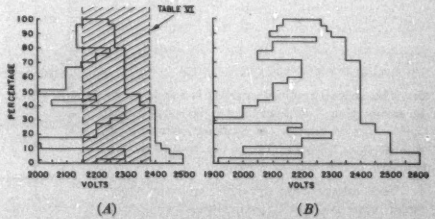



**Figure 18. Poll of industrial electrical engineers on preferred voltage variations for 2,200-volt motors**

*A—Recommended*
*B—Permissible*

Table VII. Zone and Spread of Primary Supply System Voltages in Which the Transformers of Ratios of Table VIII Can Be Operated Without Automatic Voltage Regulation and Yet Meet Limits of Table I in Most Plants

| Nominal System Voltage | Zone of Voltages on Primary of Transformers* | | Primary Voltage Spread† | |
|---|---|---|---|---|
| | Min | Max | Per Cent of Col 1 | Volts |
| 2,400 | 2,130 | 2,520 | 4 | 100 |
| 4,160 | 3,680 | 4,360 | 4 | 170 |
| 4,800 | 4,260 | 5,040 | 4 | 190 |
| 6,900 | 6,100 | 7,250 | 4 | 280 |
| 11,500 | 10,200 | 12,100 | 4 | 460 |
| 13,800 | 12,200 | 14,500 | 4 | 550 |

* Based on plant power factor of 0.85, transformer reactance 5 per cent, and 2 per cent maximum secondary feeder drop. Should power factor be higher than 0.85 or feeder drop less than 2 per cent, a lower value can be tolerated for column 2 and greater primary spread for column 4 without exceeding values given in Table I and without using voltage regulation.
† The primary voltage spread lies wholly within the zone of primary voltages.

$SR$ = Secondary no-load voltage rating of transformer
$PR$ = Primary transformer tap voltage rating
$TD$ = Voltage drop through transformer under load due to winding impedances
$FD$ = Secondary feeder or wiring drop

By interchanging the terms of this equation, the necessary applied voltage to produce a certain secondary voltage at the utilization equipment may be calculated by means of the following formula:

$$PE \approx (SE + TD + FD)PR/SR$$

In Table VII the zone and spread of voltages on primary of transformers are given, and assumptions are made regarding the transformer drop and the maximum secondary feeder drop in "Recommended Voltage Spread for Industrial Power Applications."

The per unit voltage regulation of a transformer may be calculated by the AIEE Standards approximate equation which is

$$\text{per unit regulation} = e_r \cos\phi \pm e_x \sin\phi + \frac{(e_x \cos\phi \mp e_r \sin\phi)^2}{2}$$

in which $e_r$ is the resistance drop and $e_x$ the leakage reactance drop for the transformer, both expressed in per unit; $\cos\phi$ is the power factor of the secondary load. The upper signs are used for lagging current, the lower ones for leading current.

*Transformer Taps Are Necessary.* It is economically impractical to operate all utility systems so that the voltage spread at every industrial plant is within a single narrow spread that can be tolerated without exceeding the acceptable utilization voltage spread within the plant. Most utilities, however, can maintain the primary voltage at any industrial plant within a reasonable spread but that spread may occur at various locations within a rather wide zone of primary voltages. For example, many utilities can hold the spread of primary voltage to five per cent but one utility may hold that spread between 100 and 105 per cent of nominal primary voltage while another utility holds the spread between 90 and 95 per cent of nominal voltage.

As the primary voltage spread cannot always be located favorably with respect to the nominal primary voltage, it is necessary to have primary winding taps in a transformer so that the transformer can be excited at about the same volts per turn for several locations of the voltage spread within a reasonable zone of primary voltages. The spacing between the taps in the winding determines the effectiveness of the taps for accommodating different locations of the spread. The spacing should be much less than the tolerable spread. When the tolerable spread is about five or six per cent, the tap spacing should be not more than about $2\frac{1}{2}$ per cent. A 5-per-cent tap spacing is practically useless for certain locations of the spread with respect to the tap voltage.

*Five Per Cent Taps Generally Are Not Adequate.* As shown by the cross-hatched areas in Figure 21, at some places in the primary voltage zone only a very small

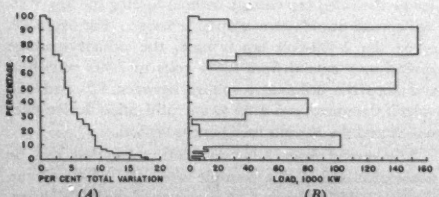



Figure 19. Poll of industrial electrical engineers on preferred voltage variations of power supply

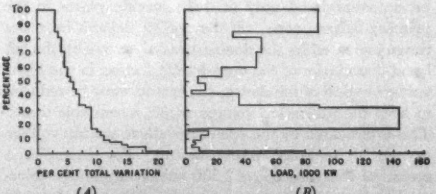



Figure 20. Poll of industrial electrical engineers on preferred voltage variations at the load

voltage spread can be permitted. Figure 21 is a graphical representation of the possible voltage relationships in a transformer having a voltage rating of 2,400 to 480 volts and one 5-per-cent tap above and one 5-per-cent tap below 2,400 volts. The no-load condition, with rated primary voltage applied to the proper tap, is shown by the bracket arrows interconnecting the upper and lower parallelograms. A primary voltage of 2,400 volts applied to the nominal tap gives 480 volts on the low-voltage side of the transformer. If 2,400 volts is maintained at the nominal tap on the primary side of the transformer and load is supplied through the transformer and low-voltage circuits in a plant in accordance with the assumptions used in this report, the voltage at some motor will be 450 volts because of voltage drops (15 volts in the transformer, 10 volts in the low-voltage feeder, and 5 volts in branch wiring). This is the spread indicated by the open area in the lower parallelogram in the sketch. The spread of 30 volts between 480 volts and 450 volts would occur in this instance if 2,400 volts were maintained on the nominal tap. The same spread would occur if 2,520 volts were maintained on the tap above the nominal tap or 2,280 volts on the tap below.

The 30 volts drop in the transformer and low-voltage circuits used in this example leaves 30 volts within the spread between 420 and 480 volts considered acceptable by the subcommittee. This remaining spread is indicated by the cross-hatched area in the utilization voltage parallelogram. This remaining 30 volts can be used for 150 volts of primary voltage spread at the 2,400-volt tap provided the primary voltage spread ranges down from the tap voltage. If the primary voltage spread begins at 2,400 volts, the primary voltage can decrease to 2,250 volts without causing the utilization voltage to fall below the acceptable limit of 420 when the 2,400-volt tap is used.

Similar primary-voltage spreads can be accommodated at other taps. For example, the primary voltage could range from 2,280 volts down to 2,138 volts if the 2,280-volt tap were used. Therefore, the zone of primary voltage that can be accommodated, by the 2,400-to-480-volt transformer with one 5-per-cent tap above and one 5-per-cent tap below 2,400 volts, is 2,520 to 2,128 volts without exceeding the acceptable spread of 420 to 480 volts. The spread of 150 volts is 6.25 per cent on the 2,400-volt base. However, a spread of 6.25 per cent can be accommodated only at three specific places in the primary-voltage zone. If the spread departs from the range indicated by the double-headed arrows on the left hand boundaries of the cross-hatched areas in the high-voltage region of the sketch, the spread must be reduced to keep the utilization voltage within acceptable limits. This is indicated by the open area above the tap voltage in the high-voltage parallelogram. For example, a spread of 150 volts above 2,300 volts could not be tolerated because the the upper 50 volts of the spread would be above the limit of 2,400 volts for the 2,400-volt tap. If the 2,520-volt tap were used, a spread of 150 volts between 2,300 and 2,450 volts would make the utilization voltage spread fall below the tolerable limit of 420 volts. The shaded area in the high-voltage region shows the limits of the primary-voltage spread as the lower end of the spread rises from 2,250 to 2,363 volts when the 2,400-volt-tap is used. With the lower end of the spread at 2,363 volts, the spread permitted is only 37 volts or 1.54 per cent.

When the lower end of the spread reaches 2,363 volts, the 2,520-volt tap can be used without causing the utilization voltage to fall below 420 volts at the lower end of the spread. Then the wider high-voltage spread, corresponding to the full length of the double-head arrow, can be accommodated. A transformer with 5-per-cent spacing of the taps cannot accommodate a primary-voltage spread appreciably wider than 1.54 per cent, if the spread may occur at any place in the primary voltage zone and the limiting utilization voltage spread and typical voltage drops listed here prevail. Of course if the primary-voltage spread is located favorably with respect to a primary tap voltage the primary-voltage spread is limited only by the part of the utilization voltage spread available to accommodate primary voltage variations. The small spread that can be accommodated at certain locations in the primary voltage zone when five per cent taps are used seriously limits the usefulness of the wide spacing of taps.

*The Desirable Transformer for Industrial Applications.* The desirable transformer would have a no-load secondary voltage rating of 575, 460, or 230 volts, and would have one $2^1/_2$-per-cent tap above and three $2^1/_2$-per-cent taps below the nominal primary voltage. The voltage relationships for the 2,400 to 460-volt case are shown in Figure 22. As in Figure 21, the bracket arrows in Figure 22 show no-load voltages when rated tap voltage is applied to the proper tap. The rated low voltage of 460 volts will occur when 2,200, 2,280, 2,340, 2,400, or 2,460 volts is applied to the corresponding tap and no-load is drawn from the transformer. The open space of the low-voltage parallelogram is the part of the allowable utilization spread that is required for the assumed typical voltage drops in the plant system. As indicated in Figure 22 by the cross-hatched portions of the parallelograms, the primary-voltage spread may extend both above and below the rated tap voltage without forcing the low-voltage spread outside the acceptable range. For example, when the 2,400-volt tap is used, the primary-voltage spread may extend from 2,348 volts to 2,505 volts and still keep the utilization voltage between 420 and 480 volts if the maximum drop to any utilization device does not exceed the 30 volts used here as typical.

The spread from 2,348 to 2,505 volts, that can be accommodated in this example when the 2,400-volt tap is used, is 157 volts or 6.55 per cent of the tap voltage. The primary voltage spread decreases as the lower limit of the spread increases from 2,348 volts to 2,407 volts as

shown by the parallelogram associated with the 2,400-volt tap. When the lower limit of the spread reaches 2,407 volts, the 2,460-volt tap can be used and a wider spread can be accommodated. But as the lower end of the spread comes up to 2,407 volts, the spread is limited to 2,505 − 2,407 or 98 volts or 4.09 per cent of the tap voltage. A similar limit occurs for other taps. Any spread not exceeding about four per cent can be accommodated at any location in the primary-voltage zone between 2,172 volts and 2,567 volts. Spreads as wide as about 6.5 per cent can be accommodated at five favorable locations in the same zone.

There are two important advantages to using a transformer ratio and tap arrangement such as illustrated in Figure 22. One advantage is that the rated low voltage of the transformer is the same as the nominal voltage of the system it supplies and the same as the average voltage that frequently appears at the low-voltage terminals of the transformer or at major load centers in the plant system under average load conditions. The other advantage is that the primary voltage spread can extend both ways from the tap voltage with the larger part of the tolerable spread above the tap voltage. The result is that the transformer is excited at a voltage near the rated value. The transformer is operated around its rated voltage instead of below its rated voltage as is necessary for a transformer operated as shown in Figure 21. To use the ratios and tap arrangements typified by Figure 22 eventually would require a complete departure from present standard transformer ratios and tap arrangements in the range of sizes and voltages used in industrial applications.

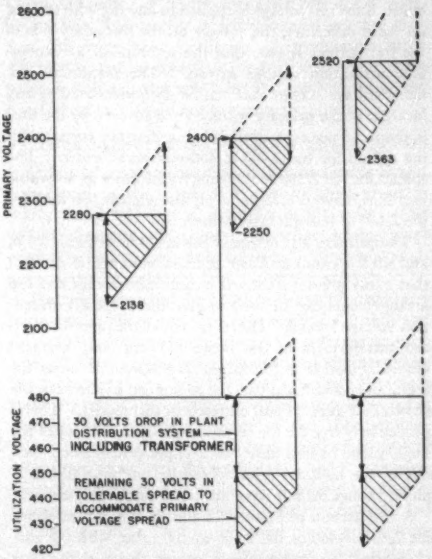



**Figure 21. Voltage relationships for a transformer rated at 2,400 to 480 volts with one 5-per-cent tap above and one 5-per-cent tap below 2,400 volts**

*Present Standard Transformers.* Present standard transformers have no-load secondary voltage ratings of 600, 480, or 240 volts, and in many instances have two $2^1/_2$-per-cent taps above and two $2^1/_2$-per-cent taps below the nominal primary voltage. The voltage relationships for a 2,400-to-480-volt transformer, typical of the present standard ratings, is shown in Figure 23.

The construction of the chart in Figure 23 is the same as that in Figures 21 and 22. In Figure 23 the primary voltage spread must be all down from the tap voltage be-

**Table VIII. Recommended Transformer Ratings and Taps for Industrial Power Systems**

| Nominal System Voltage | High-Voltage Rating | No-Load Low-Voltage Rating | Full-Capacity High-Voltage Tap Location, Per Cent | |
|---|---|---|---|---|
| | | | Above | Below |
| 230 | 230 | 120 or 208Y | None | None or 2, $2^1/_2$ |
| 460 | 460 | 120 or 208Y | None | None or 2, $2^1/_2$ |
| 575 | 575 | 120 or 208Y | None | None or 2, $2^1/_2$ |
| 2,400 | 2,400 | 120 or 208Y | None | 4, $2^1/_2$ |
| 2,400 | 2,400 | 240, 480, 600 | 2, $2^1/_2$ | 2, $2^1/_2$ |
| 4,160 | 4,160 | 120 or 208Y | None | 4, $2^1/_2$ |
| 4,160 | 4,160 | 240, 480, 600 | 2, $2^1/_2$ | 2, $2^1/_2$ |
| 4,800 | 4,800 | 120 or 208Y | None | 4, $2^1/_2$ |
| 4,800 | 4,800 | 240, 480, 600 | 2, $2^1/_2$ | 2, $2^1/_2$ |
| 6,900 | 6,900 | 120 or 208Y | None | 4, $2^1/_2$ |
| 6,900 | 6,900 | 240, 480, 600 | 2, $2^1/_2$ | 2, $2^1/_2$ |
| 12,000 | 12,000 | 120 or 208Y | None | 4, $2^1/_2$ |
| 12,000 | 12,000 | 240, 480, 600 | 2, $2^1/_2$ | 2, $2^1/_2$ |
| 13,200 | 13,200 | 120 or 208Y | None | 4, $2^1/_2$ |
| 13,200 | 13,200 | 240, 480, 600 | 2, $2^1/_2$ | 2, $2^1/_2$ |
| 13,800 | 14,400 | 120 or 208Y | None | 14.1, 13.8, 13.5, 13.2 |
| 14,400 | 14,400 | 240, 480, 600 | None | 14.1, 13.8, 13.5, 13.2 |

Note: All high-voltage taps to have fully kilovolt-ampere capacity.

cause, if the tap voltage is applied to any tap with no load on the transformer, the voltage on the secondary side of the transformer is 480 volts, the top limit of the acceptable utilization voltage spread. The maximum primary voltage spread that can be accommodated at any location in the primary voltage zone covered by the taps is about 3.9 per cent, or slightly less than the corresponding spread for the 2,400-to-460-volt transformer. The spread for the 2,400 to 480-volt transformer at favorable locations is about 6.25 per cent, also slightly less than for the 2,400 to 460-volt transformer.

The primary advantage of the 2,400 to 480-volt ratio, and similar ratios at other primary voltages, is the fact that many present standard transformer ratings and tap arrangements can be used to give the proposed utilization voltage spread. However, not all the present standard transformers in the range of sizes and voltages generally used in industrial plants satisfactorily meet the requirements for industrial use as implied by the example shown in Figure 23 and outlined in this report. This is particularly true for the tap arrangements. Many of the single-phase ratings have two $2^1/_2$-per-cent taps on each side of the nominal primary rating, but most of the 3-phase ratings do not have adequate tap arrangement.

A comparison of Figures 22 and 23 shows that either the 2,400-to-460 or the 2,400-to-480 ratio, with the corresponding tap arrangements, covers about 95 per cent of the primary-voltage zone of 2,130 to 2,520 volts. The

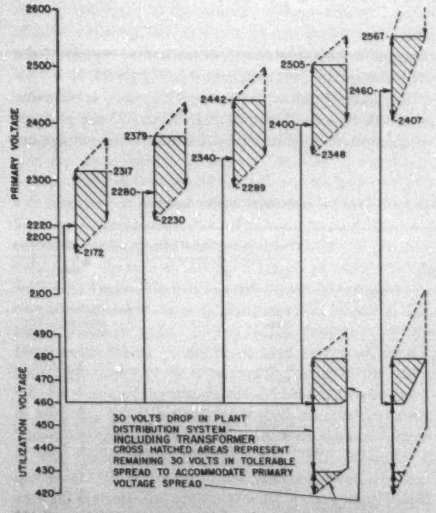



**Figure 22. Voltage relationships for a transformer rated at 2,400 to 460 volts with one $2^1/_2$-per-cent tap above and three $2^1/_2$-per-cent taps below 2,400 volts**

2,400-to-480-volt transformers with two $2^1/_2$-per-cent taps on each side of 2,400 volts can accommodate voltages between 2,138 and 2,520 volts provided that the spread does not exceed 3.9 per cent at the most unfavorable locations in the zone or 6.25 per cent at the most favorable locations. The 2,400-to-460-volt transformer accommodates voltages in a zone from 2,172 volts to 2,567 volts with a spread limit of 4.0 per cent of unfavorable locations and 6.5 per cent for favorable locations. The 2,400 to-480-volt transformer does not reach the upper limit of the proposed zone and the 2,400-to-460-volt transformer does not reach the lower limit.

Using the voltage drops suggested in Table II, the same conclusions would be reached.

*To Illustrate Further the Application of a Transformer.* Using the data of Table II, assume a transformer is to supply a 460-volt system from a 2,400-volt system. In Table VII the primary voltage zone is given as 2,520 to 2,130 volts. It is desired to maintain the secondary voltage spread within the limits of 480 and 420 volts. Assume a 2,400-to-480-volt transformer has two $2^1/_2$-per-cent taps above and two $2^1/_2$-per-cent taps below rated primary voltage. Thus, the transformer would have primary voltage ratings of 2,520, 2,460, 2,400, 2,340, and 2,280 volts. Also assume that primary voltage spread, transformer drop, and wiring drop are respectively 20. 15, and 13 volts (460-volt base).

With 2,520 volts ($A_1$) applied to the transformer, set on the 2,520-to-480-volt tap, a maximum no-load secondary voltage of 480 volts, and a minimum voltage at full load of $480-(15+13)=452$ volts will result. (See Figure 24, curve 1.) At the lower limit of the primary voltage spread, 2,410 volts ($A_2$) the minimum secondary voltage at full load would be $460-(15+13)=432$ volts. (See Figure 24, curve 3.) For this primary spread, the secondary voltage spread is 480 to 432 volts, a total of 48 volts. This is an illustration of optimum location of maximum primary voltage with respect to tap setting.

However, let us now consider a case where primary voltage spread is at the most adverse location with respect to the tap setting. This is represented in Figure 24 by $B_1$ and $B_2$, or primary voltages of 2,461 and 2,350 volts. Here, the maximum primary voltage is higher than the next lower tap rating, and, therefore, it would give a voltage higher than 480 volts if the lower tap were used. Consequently, the 2,520-to-480-volt tap must be used, giving a maximum voltage at no load of 468. At full load the minimum secondary voltage would be $468-(15+13)=440$ volts. (See Figure 24, curve 2.) At the lower limit of this primary voltage spread, $B_2$, the maximum secondary voltage with no load on the system would be 448 volts, and the minimum secondary voltage would be $448-(13+15)=420$ volts. (See Figure 24, curve 4.) The secondary voltage spread for this primary voltage spread would be 468 to 420 volts, also a total of 48 volts.

Of course, the maximum value of the primary voltage could be any value between 2,520 and 2,461 volts, with

**Table IX. Examples of Tables I and VII Applied to a 120-Volt System Supplied From a 460-Volt System**

| Item | Volts |
|---|---|
| 1. Voltage at terminals of devices with transformer lightly loaded and with primary voltage at a maximum value | 125 |
| 2. Full-load voltage at terminals of farthest devices with supply voltage at a minimum and with full load on transformer | 114 |
| 3. Total voltage spread, difference between items 1 and 2 | 11 |
| 4. Assumed allocation of voltage spread of item 3, suggested as reasonable values applying in majority of cases | |
| Voltage spread in primary supply (120-volt base) | 8 |
| Less drops at light loads | −2 |
| | 6 |
| Voltage drop through transformer (120-volt base) | 2 |
| Voltage drop in secondary wiring | 3 |
| 5. Zone of primary supply voltage | 434–475 |

**Table X. Primary Voltages Corresponding to Transformer Secondary Voltages at No Load in Figure 24.**

| Transformer Tap Setting | Secondary Voltage | | | |
|---|---|---|---|---|
| | $A_1 = 480$ | $A_2 = 460$ | $B_1 = 468$ | $B_2 = 448$ |
| 2,280/480 | 2,280 | 2,190 | 2,220 | 2,130 |
| 2,340/480 | 2,340 | 2,240 | 2,280 | 2,180 |
| 2,400/480 | 2,400 | 2,300 | 2,340 | 2,240 |
| 2,460/480 | 2,460 | 2,360 | 2,400 | 2,300 |
| 2,520/480 | 2,520 | 2,410 | 2,460 | 2,350 |

corresponding variations of minimum value of primary voltage, and of location of secondary voltage spread.

Similar conditions exist for other primary voltages, as can be seen by comparing the various primary voltages corresponding to the points $A_1$, $A_2$, $B_1$, and $B_2$ in Table X (see Figure 24) where for example, $B_2$ for the lowest (2,280 to 480 volt) tap is given as 2,130 volts. This voltage is the minimum which this transformer can handle under the assumed conditions.

It might be thought that the total spread shown in Figures 24, between $A_1$ and $B_2$, might be handled by this transformer without exceeding the recommended voltage spread. This is true. But with this primary spread, if this secondary system is to supply a lighting transformer, it then would not be possible to keep the voltage spread on the lighting system within recommended limits.

For a 120-volt system supplied from a 2,400-volt system, a similar analysis will show that the required transformer should be rated 2,400 to 120 volts and should have four $2^1/_2$-per-cent taps, but in this instance all should be below rated primary voltage. This is so because the secondary spread is partly above the rated transformer secondary voltage, rather than all below as was the case previously.

A 120-volt system supplied from a 460-volt system will have a transformer connected on the secondary side of the transformer previously discussed. Therefore, as can be seen by referring to Figure 24, the primary voltage zone is 480 to 434 volts, and the primary voltage spread is 35 volts. However, the upper part of this zone and the full extent of the spread seldom will occur. For this reason, it is assumed in Table IX that the primary zone is 475–434 volts, and the primary spread is 30 volts.

The recommended spread on the 120-volt system is 125 to 114 volts. A transformer rated 460 to 120 volts, having two $2^1/_2$-per-cent taps below rated primary voltage, will meet these conditions. A transformer rated 480-to-120, having four $2^1/_2$-per-cent taps below rated primary voltage, also will meet the conditions but the two highest taps would not be used or required.

## RECOMMENDED TRANSFORMER RATINGS AND TAPS

Industrial power transformer ratings preferably should correspond to the nominal system voltages given in Table I and VI, that is, multiples of 115 volts. This would eliminate the present confusion among plant engineers and hence would correct the prevalent tendency toward excessively high utilization voltages.

The choice between the 2,400-to-460-volt transformers with one tap above and three taps below 2,400 volts and the 2,400-to-480-volt transformer with two taps on each side of 2,400 volts is a choice between the desirable operating characteristics of the former and adherence to present standard transformer designs and operating practices of utilities. The majority choice of this subcommittee favors the use of present standard transformer designs where they agree with the general ratio and tap arrangement illustrated in Figure 23. This avoids a complete change of transformer standards in the range of sizes and voltages generally used in industrial plants and permits a continuation of the utility practice of using transformers that give 240, 480, or 600 volts for general utilization voltage service to small power users.

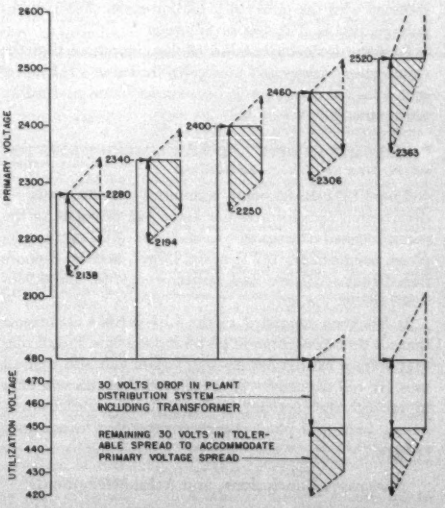



**Figure 23. Voltage relationships for a transformer rated at 2,400 to 480 volts with two $2^1/_2$-per-cent taps above and two $2^1/_2$-per-cent taps below 2,400 volts**

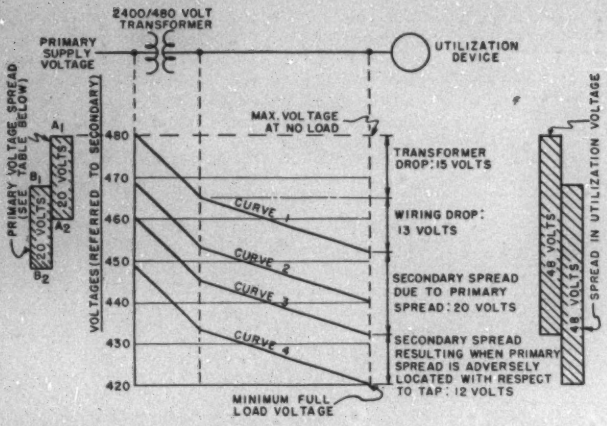



**Figure 24. Voltages in typical industrial plant**

*A 460-volt system supplied from a 2,400-volt system in accordance with Tables I, VII, and VIII*

During the past few years there has been a strong trend toward supplying industrial plant lighting from the power distribution system through relatively small low-voltage transformers. Present ratings of transformers available for this service are not adequate unless provided with four $2^1/_2$-per-cent taps below normal. Considerable savings could be realized if the transformers were rated suitably so that no taps, or at the most two $2^1/_2$-per-cent taps below normal, would be required. This is possible if the transformer primary rating corresponded with the power distribution system full-load bus voltage, that is, 230, 460, or 575 volts.

It is the majority opinion of the committee that the transformer ratings and taps given in Table VIII represent a logical compromise between industrial and utility requirements.

### AGREEMENTS WITH AND RECOMMENDATIONS TO EEI–NEMA

The EEI–NEMA joint committee on standards for distribution transformers has agreed in principle to the recommended ratings given in Table VIII for single-phase transformers 167 kva and larger, and for 3-phase transformers 150 kva and larger, except for the 6,900-volt primary rating.

It has been suggested to the EEI–NEMA committee that all transformer name plates should state specifically that voltage ratings are no-load values and also that all taps are full capacity. It is believed that this will help to correct the present widespread misunderstanding among industrial plant engineers regarding transformer ratings.

## Summary, Conclusions, and Acknowledgments

A study of industrial voltage requirements has been made. This study was concerned mainly with industrial plants supplied at a nominal primary voltage of 2,400 or higher. Considerations were given primarily to the following aspects of the problem:

1. Voltage spreads at the terminals of utilization equipment.

(a). Effects of voltage spreads on performance of apparatus (summarized in Tables III, IV, and V).

(b). Survey of voltage spreads actually occurring in industry (summarized in Figures 15–19).

(c). Recommended voltage spreads (Tables I and VI).

2. Voltage drops in industrial distribution systems.

3. Voltage zones and voltage spreads of the primary supply.

4. Recommendations on nominal system voltages (Tables I, VI, and VII).

5. Voltage ratings and taps for industrial power transformers (Table VIII and the preceding paragraphs).

It is to be observed that the transformer ratings and taps recommended in "Recommended Transformer Ratings and Taps" do not meet the industrial needs quite as well as those mentioned in "The Desirable Transformer for Industrial Applications." The reasons for the committee's recommendation are stated with the recommendation.

It is also to be noted that some of the nominal system voltage designations recommended are not in agreement with the present recommendations of the EEI and NEMA. It is the recommendation of the committee that nominal system voltage designation should correspond more nearly to the average voltage occurring at full load rather than to the maximum recommended limit (Table I). It is suggested further that the EEI–NEMA committee consider the recommendation of this committee regarding nominal system voltage designations.

This report will have served a useful purpose if it achieves a fuller understanding of the voltage requirements for satisfactory operation of industrial electric apparatus, and encourages a more adequate consideration, by those concerned, of the problems involved and their solution.

The plant electrical engineer, having an intimate knowledge of the particular conditions at his plant, may take advantage of this knowledge to provide the optimum voltage conditions in his plant.

Where primary voltage zones and spreads are worse than those assumed in this report, it may be possible to make suitable modifications in the design of one or more of the elements of the system, or in some instances, to provide voltage regulation for all or part of the load, as, for example, the lighting load.

# INSTITUTE ACTIVITIES

## North Eastern District to Meet in New Haven, Conn., April 28–30

A program of broad interest has been arranged for the 3-day meeting of the North Eastern District to be held in New Haven, Conn., April 28–30, 1948. Meeting headquarters will be in the Hotel Taft. A variety of subject matter appropriate for the locality of the meeting will be presented in ten technical sessions, and in addition there will be a general session of interest to many members and two sessions or more of student papers. A special program for the women, inspection trips to nearby industries, and entertainment in the evenings assure a busy time.

### INSPECTION TRIPS

Some inspection trips have been scheduled over the entire duration of the meeting to permit those attending to take in more than one trip if desired. Trips not scheduled on Friday have been arranged so that there will be as little conflict as possible with related subject matter on the program.

### WOMEN'S PROGRAM

A special program for the women will include luncheon at the Yale Faculty Club on Wednesday followed by a tour of the campus in the afternoon. On Thursday, there will be a luncheon in one of the suburbs of New Haven with an afternoon trip to the Peabody Museum of Yale. Friday a bus trip will be taken to Bridgeport for luncheon and a program at the General Electric Company Consumers' Institute. Teas, bridge, and other activities are planned, details of which will be announced at the time of the meeting.

### ENTERTAINMENT

Thursday evening there will be a social hour, followed by an informal banquet and evening of varied entertainment. Wednesday there will be an opportunity to attend a presentation by the Yale Dramatic Association at the Yale University Theater. This will be found to be different from the usual theatrical presentation. A block of seats has been reserved (please contact the registration desk early).

### ADVANCE REGISTRATION

Members of the district who receive an advance registration card should fill in and mail the card promptly to E. D. Lynch, Chairman of the Hotel and Registration Committee, Westinghouse Electric Corporation, P. O. Box 1817, New Haven 6, Conn. Registration in advance will assist committees which are making arrangements for the meeting. Registration should be completed at the desk on arrival at the meeting.

Library and campus of Yale University, New Haven, Conn.

### HOTEL RATES

Meeting headquarters will be in the Hotel Taft on the New Haven Green. Hotel facilities will be overtaxed at the time of the meeting, hence members are urged to make hotel reservations at once. The Hotel Duncan is less than three blocks away and only a short walk. If rooms are not available at either of these two hotels, the hotel and registration committee in New Haven will make an effort to obtain a reservation at one of the other hotels. See Table I for rates.

### DISTRICT MEETING COMMITTEE

The District meeting committee comprises:

J. F. Walker, *general chairman;* E. W. Davis, vice-president, North Eastern District; Victor Siegfried, secretary, North Eastern District; E. R. McKee, chairman, Student activities, North Eastern District; E. G. Horton, secretary-treasurer, Connecticut Section; H. F. Brown; B. H. Caldwell; E. R. Coop; W. S. Fielding; C. D. Hewitt; H. C. Lindberg.

The chairmen of the subcommittees are

H. O. Anderson *finance;* H. F. Brown, *technical program;* F. W. Buck, *publicity and printing;* A. G. Conrad, *Student program;* E. D. Lynch, *hotel and registration;* J. A. Nixon, *entertainment;* W. A. Upham, *inspection trips and transportation;* Mrs. C. A. Williams, *ladies' program.*

**Table I. Hotel Rates**

| | Hotel Taft | Hotel Duncan |
|---|---|---|
| Double room with bath: | | |
| For one person | $7 | $6 |
| For two persons | 7 | 7 |

## Subjects Announced for Rubber and Plastics Meeting

The AIEE subcommittee on rubber and plastics industries of the general industry applications committee, jointly with the Akron Section of AIEE, is sponsoring a full-day technical conference on electrical problems in the rubber and plastics industries.

The meeting will be held at Akron, Ohio, from 8:30 a.m. to 5:30 p.m., on Tuesday, April 20, 1948, in the auditorium of the M. O'Neil Company's department store.

The technical papers will include

1. **Electric Power Systems for Small Rubber Plants.** *B. D. Morgan,* Johnson and Johnson Company; *R. S. Ferguson,* Goodyear Tire and Rubber Company; *H. J. Finison,* General Electric Company.

2. **D-C Spot Conversion for Rubber and Plastics Manufacturing Plants.** *C. E. Robinson,* Reliance Electric and Engineering Company.

3. **Separate Electric Equipment Rooms Versus National Electrical Manufacturers Association Enclosures for Protection of Motors and Control.** *F. A. Green,* F. B. Goodrich Company.

4. **Electric Braking of Rubber Mills and Calenders.** *B. J. Dalton,* General Electric Company.

5. **Classification of Electric Drive Characteristics for Rubber Machinery.** *A. T. Bachelet,* Westinghouse Electric Corporation.

6. **The Measurement and Control of Tension and Its Relation to Motor Input.** *H. L. Smith,* General Electric Company.

7. **Temperature Measurement and Controls in the Rubber and Plastics Industries.** *F. L. Spangler,* Leeds and Northrup Company.

It is expected that the meeting will be attended by many engineers of the rubber and plastics industries. K. W. John (M '41) of the United States Rubber Company, Detroit, Mich., will preside.

# Tentative Program

# North Eastern District Meeting, New Haven, Conn., April 28–30, 1948

## Wednesday, April 28

### 8:30 a.m. Registration

### 9:30 a.m. Rotating Machinery

**48-110. Progress Report on AIEE-ASME Standard Large 3,600-rpm Turbine-Generators.** *S. H. Mortensen*, Allis-Chalmers Manufacturing Company; *J. B. McClure*, General Electric Company; *C. M. Lafoon*, Westinghouse Electric Corporation

**48-161. Performance Calculations of Induction-Type Frequency Converters.** *F. R. Latzko*, Electric Specialty Company

**48-162. Balanced Fractional-Slot Wave Windings.** *M. M. Liwschitz*, Polytechnic Institute of Brooklyn

**48-163. Doubly Chorded or Doubly Shifted Fractional-Slot Lap and Wave Windings.** *M. M. Liwschitz*, Polytechnic Institute of Brooklyn

**48-164. Operation of Large D-C Motors from Controlled Rectifiers.** *A. Schmidt, Jr., W. P. Smith*, General Electric Company

**48-165. Steady State Stability of Synchronous Machines as Affected by Angle Regulator Characteristics.** *C. Concordia*, General Electric Company

### 9:30 a.m. Transformers, Cables, and Insulation

**48-174. A New Line of Oil-Filled Bushings.** *B. N. Bowers, D. L. Johnston*, General Electric Company

**48-175. Electrical Properties of Ceramics as Influenced by Temperature.** *E. W. Lindsey, L. J. Berberich*, Westinghouse Electric Corporation

**48-176. Statistical Methods as Applied to the Manufacture and Testing of Wire and Cable.** *M. G. Woolfson*, General Cable Company

**48-177. Feeder Voltage Regulator Accuracy Standards.** W. E. Birchard, General Electric Company

### 9:30 a.m. Instruments and Electronics

**48-171. A New Line of Thyratrons.** *A. W. Coolidge, Jr.*, General Electric Company

**48-172. Frequency Response Characteristics of Recording Instruments.** *T. D. Graybeal*, University of California

**48-173. An Instrument for Recording Continuously the Salinity, Temperature, and Depth of Sea Water.** *A. W. Jacobson*, The Bristol Company

### 2:00 p.m. Industry Applications—Textile Machinery

**DP.* Selection of Electric Drive for Looms.** *R. J. Demartini, A. F. Lukens*, General Electric Company

**DP.* Trends in Loom Design and Their Effect on Drive Requirement.** *Victor Seperich*, Crompton and Knowles Loom Works

**DP.* Minimizing Fire Hazards of Electric Equipment on Looms.** *C. F. Hedlund*, Associated Factory Mutual

**DP.* Slasher Drives.** *C. E. Crater*, Westinghouse Electric Corporation

**DP.* Drive Requirements for Cotton and Rayon Slashers.** *Frank Rose*, Dan River Mills

**DP.* Drive Requirements for Worsted Slashers.** *Paul Wengel*, Uxbridge Worsted Company

### 2:00 p.m. Circuit Breakers and Switchgear

**48-166. An Improved Design of Low-Voltage Panel-Mounted Air Circuit Breaker.** *L. H. Sparow, J. A. Fawe*, General Electric Company

**48-169. A New Isolated Phase Metal-Enclosed Bus Designed for High Capacity Generating Stations.** *B. W. Wyman, R. B. Shores*, General Electric Company

**48-170. Circuit Breaker Modernization and Faster Fault Clearing on Single-Phase Electrified Railroad.** *H. F. Brown*, N. Y., New Haven & Hartford Railroad; *H. A. Travers, C. A. Woods, Jr.*, Westinghouse Electric Corporation

### 2:00 p.m. Special Industry Applications

**DP.* Electric Braking for Rubber Mills and Calenders.** *B. J. Dalton*, General Electric Company

**DP.* Electric Equipment for Plastic Injection Molding Machines.** *M. Morgan*, Reed Prentice Company

**DP.* High-Frequency Circuits for Internal Grinding Machines.** *L. Morrill, S. Rice*, Heald Machine Company

### 2:30 p.m. Women's Program

Tour of Yale University campus

### 3:00 p.m. Inspection Trips

J. B. T. Instruments, Inc. Manufacturer of indicating and test instruments

A. C. Gilbert Company. Manufacturer of light appliances and toys

Information about point of departure will be found on the bulletin board on the mezzanine

## Thursday April 29

### 9:30 a.m. General Session

Address of welcome. Ernest W. Davis, vice-president, AIEE North Eastern District

Remarks on Institute affairs. Blake D. Hull, AIEE president

**Address: Maintaining National Strength and Industrial Production Through Conservation of Our Resources.** *T. J. Russell*, chairman, Connecticut Technical Council

**Address: Electric Power Supply of the United States With Special Emphasis on the Northeast.** *Clarence W. Mayott*, Connecticut Valley Power Exchange

### 12:00 m. District Executive Committee Luncheon

### 2:00 p.m. Power and Land Transportation

**DP.* Interchange Accounting Procedure of the Connecticut Valley Power Exchange.** *E. C. Brown*, Connecticut Valley Power Exchange

**DP.* Highlights of Electric and Diesel-Electric Locomotive Operation.** *P. H. Hatch*, N. Y., New Haven & Hartford Railroad

**DP.* Railroad Mobile Communication.** *R. W. Tuttle*, N. Y., New Haven & Hartford Railroad

During the afternoon there will be an inspection of a New Haven Railroad Diesel-electric locomotive and an electric locomotive. Arrangements will be announced on the bulletin board on the mezzanine

### 2:00 p.m. Relays and Protective Devices

**48-178. A New Reactance Distance Relay.** *G. G. Dewey, J. R. McGlynn*, General Electric Company

**DP.* How Much Back-up for a Bus Protective Scheme.** *C. A. Molsberry, J. M. Moore*, United Illuminating Company

**DP.* An Application of Carrier Relaying to a 3-Terminal 115-kv Line.** *V. J. Hayes*, Connecticut Light and Power Company

**DP.* Limiter Applications in Underground Secondary Networks.** *J. A. Rogoff*, Burndy Engineering Company

### 2:00 p.m. Wire Drawing Machinery

**DP.* Variable Voltage Control on Multimotor Wire Blocks.** *O. M. Bundy*, Clark Controller Company

**DP.* Rotating Equipment for Use on Constant Potential and Variable Voltage Wire Blocks.** *Dick Gueder*, Reliance Electric and Manufacturing Company

**DP.* Flexibility of Multimotor Multispindle Tandem Wire Block Control.** *D. E. Donaldson*, Electric Controller and Manufacturing Company

**DP.* Electric Drive for Wire Winders.** *H. R. Lloyd*, General Electric Company

**DP.* Wire Drawing Processes.** *Roger Bryant* American Steel and Wire Company

### 3:00 p.m. Women's Program

Trip to Peabody Museum of Yale University

## Friday, April 30

### 9:30 a.m. Special Industrial Applications and Heating

**DP.* A Quick Look at the Heat Pump.** *C. A. Williams, E. Haw Walton*, United Illuminating Company

**DP.* The Heat Pump in New England—Progress Report of Heat Pump Study.** *C. H. Coogan, Jr.*, University of Connecticut

**DP.* Application of Eddy Current Coupling to Wind Tunnel Drive.** *F. W. Sams*, Pratt and Whitney Aircraft

---

**—PAMPHLET reproductions of author's manuscripts of the numbered papers listed in the program may be obtained as noted in the following paragraphs.**

**—PRICES for papers, irrespective of length, are 30 cents to members (60 cents to nonmembers) whether ordered by mail or purchased at the meeting. Mail orders are advisable, particularly from out-of-town members, as an adequate supply of each paper at the meeting cannot be assured. Only numbered papers are available in pamphlet form.**

**—COUPON books in five-dollar denominations are available for those who may wish this convenient form of remittance.**

**—THE PAPERS regularly approved by the technical program committee ultimately will be published in PROCEEDINGS and TRANSACTIONS; also, each is scheduled to be published in ELECTRICAL ENGINEERING in digest or other form.**

---

Immediately following this meeting (approximately 400 p.m.) will be a tour of the heat pump installation in the same building as the meeting.

### 9:30 a.m. Communication

**DP.* Mobile Telephone Service—General Problems.** *L. B. Grew*, Southern New England Telephone Company

**DP.* Mobile Telephone Service—Technical Aspects.** *J. M. Henry*, New England Telephone and Telegraph Company

**DP.* Mobile Telephone Service—Special Applications.** *D. S. Dewire*, New York Telephone Company

**DP.* Microwaves in New England.** *C. R. Moore*, American Telephone and Telegraph Company

### 9:30 a.m. Student Sessions

**Increasing the Natural Resonant Frequency of Electromechanical Oscillating Systems.** *G. Gamble*, University of Connecticut

**A Simplified Gaussmeter for Measurement of Steady Magnetic Fields.** *J. Biggerstaff*, University of Connecticut

**Electrical Engineering Education.** *E. S. Rosett*, University of Connecticut

**Multiplexing of Audio Channels by Time Division.** *George Arthur*, Yale University

**Synthesis of Stagger Tuned Intermediate-Frequency Amplifiers.** *S. E. Church*, Yale University

**Sectional Equipment—A Means of Reducing Cost of Maintenance and Repair.** *Caleb Didriksen*, Yale University

**An Infinite Impedance Detector.** *D. T. Feldman*, Yale University

**Testing Methods for Transients in Audio Amplifiers.** *T. R. Hodge*, Yale University

**A Transient Oscilloscope.** *P. M. Schultheiss, R. R. Shaak*, Yale University

**Properties and Applications of Selenium Rectifiers.** *A. L. Odmark*, Yale University

**The Theory of the Polyphase Commutator Type of Speed Regulator.** *W. W. Henderson*, Yale University

### 12:00 m. Women's Program

Trip to Bridgeport and General Electric Company Consumers' Institute

### 2:00 p.m. Inspection Trips

Dunham Laboratory of Yale University

General Electric Company, wire and cable division, by bus to Bridgeport

General Electric Company, Consumers' Institute, by bus to Bridgeport (primarily for the women)

Winchester Repeating Arms Company

The United Illuminating Company, 30,000-kw unit under construction

Rockbestos Company—heat- and flame-proof cable

N. Y., New Haven & Hartford Railroad, 10,000-reactive-kilovolt-ampere capacitor station by bus

American Steel and Wire Company, steel wire drawing

Information about point of departure will be found on the bulletin board on the mezzanine

Inspection of The United Illuminating Company Heat Pump and the N. Y., New Haven & Hartford Railroad capacitor station may be made at other times by special arrangement. Contact the registration desk on the mezzanine

*DP: District paper; no advance copies are available; not intended for publication in *TRANSACTIONS*.

## Publication Date Changed for AIEE Year Book

Effective with the 1948 edition, the "AIEE Year Book" will be published and distributed in the early fall, probably during September, instead of early in the spring as it has been in recent years. The objective of this change is to make available at the beginning of the AIEE administrative year an up-to-date roster that will be a maximum service to the new officer and committee personnel and other members active in AIEE affairs. This change was recommended by the publication committee and approved by the board of directors at Pittsburgh in January. The decision also was made to continue issuance of the Year Book with the same general format and arrangement that has prevailed since 1934. It was decided further that the Year Book would continue to be distributed automatically upon issuance only to the working group of the membership comprising the local, District, and national officers, and to the personnel of national committees, but that copies also would be made available without charge to any Associate, Member, or Fellow of the Institute upon written application to AIEE headquarters.

The study of the "AIEE Year Book" situation was made by the publication committee in accordance with comments and suggestions made by the board of directors at its November meeting in Chicago during the Midwest general meeting. The two principal questions raised were the most effective and useful date of issuance, and the most effective and useful arrangement of the membership listings contained in the Year Book. The present form and arrangement of the Year Book has been used since 1934, when it was adopted as a part of a general renovation of the Year Book in accordance with a survey of membership opinions, and recommendations. However, representations had been made to the board of directors that the Year Book would be more generally useful if the arrangement of the present two main divisions were reversed, placing the main individual membership informational items in strictly alphabetical sequence regardless of geographic location, leaving the geographic listing to carry surnames only as a key listing of local Section affiliation and geographic distribution. This was in effect a suggestion to revert to the style abandoned in 1932.

### QUESTIONNAIRE SURVEY

Knowing that opinions on this latter suggestion differ widely among members, and depend upon the nature of the use made of the Year Book by the individual member, the publication committee sought to obtain firsthand comment from the members who make the most use of the Year Book. Accordingly some 500 questionnaires and return-postal card ballots to the working group comprised of the members of the board of directors, the chairmen of all national committees, District secretaries, District membership chairmen, chairmen of District committees on Student activities, counselors of Student Branches, and the chairmen, vice-chairmen, and membership chairmen of all Sections. A return of 295 ballots from this group revealed the following range of opinion:

1. 165 for continuing the present form and arrangement of the Year Book without change.
2. 105 for a return to the straight alphabetical listing of membership informational items.
3. 25 stating no preference.
4. No disagreement with the proposal to change the date of issuance of the Year Book to the beginning of the administrative year in the late summer or early fall.

The new publication schedule for the Year Book will require special effort by the responsible personnel of each Branch, Section, District, and national committee to assure that the appropriate listings of

**The 30,000-kw unit under construction by the United Illuminating Company which will be inspected during the North Eastern District meeting**

administrative and operating personnel as required for the Year Book are available at AIEE headquarters for printing by August 1, the beginning of the administrative year, instead of from two to six months later as has been the prevailing casual practice.

## Prices Changed for Advance Pamphlets of Papers

Hereafter, advance pamphlet copies of authors' manuscripts of technical program papers, popularly known as "preprints," will be available at the flat price of 30 cents per copy to members, 60 cents per copy to nonmembers, instead of at the sliding scale of prices heretofore prevailing on the basis of the physical size of the individual paper. Also, there has been a substantial reduction in the authorized free distribution of these papers. These actions were taken by the publication committee at its January meeting in Pittsburgh during the recent winter general meeting, in response to recommendations from the finance committee and the board of directors that this very specialized phase of AIEE publication services be made more nearly self-supporting.

The primary purpose in continuing the relatively expensive process of producing these "preprints" is to make copies of the regularly approved technical program papers available to interested members at the very earliest possible dates, to enhance the opportunity for more effective discussion of the papers as presented at the general or District meetings for which they are scheduled. The use of the photolithographic process of reproduction for this purpose enables copies of the papers to be made available in a relatively short-time interval that is completely impossible of attainment through letter-press printing processes.

The new policy governing the distribution of these papers embraces the following provisions:

1. Not to exceed five copies of a paper to be sent automatically and without charge to each author of that paper.

2. Not to exceed ten copies of each paper reviewed and approved by a particular committee will be made available for distribution without charge at the discretion of the chairman of that committee, expressly for the purpose of inviting and stimulating specific discussions.

3. No other free distribution to be made.

4. Any member or Student member may obtain copies at meetings, or at AIEE headquarters by personal visit or mail order, at the flat price of 30 cents per copy; nonmembers at 60 cents per copy.

5. After the initial requirements for a meeting have been met, quantity reproductions, in multiples of 100, can be obtained through Institute headquarters by authors, or by the organization with which the authors are affiliated; estimates for such orders will be furnished upon request.

## Technical Paper Digests to Replace Abstracts

Instead of the very much abbreviated abstracts of technical program papers heretofore published periodically in groups in *ELECTRICAL ENGINEERING*, more comprehensive digests will be the rule hereafter, in accordance with action taken by the AIEE publication committee at its meeting in Pittsburgh during the recent winter general meeting. Whereas the previous abstracts were supposed to be limited to an average of about 150 words, the new plan calls for digests of from 500 to 700 words of text matter which may be supplemented by one or two pertinent illustrations.

There were at least two major reasons for making this change. One was to aid in overcoming increasing publication production difficulties related to the steadily growing technical program activities of AIEE meetings, and the other was to provide a more complete and better co-ordinated reader service.

When the policy of publishing the brief abstracts first became effective in 1938, the principal objective sought was, in effect, an amplification of the various titles of the technical program papers as scheduled for the various national and District meetings. Correspondingly, the abstracts were supposed to be available for publication well in advance of the meetings to aid members in determining what advance copies of papers they would like to request for the purpose of preparing advance discussions for the meeting. Although the original objective of early advance publication never fully materialized, reasonably satisfactory results were attained over the first few years. However, with the heavy and sustained growth of AIEE technical programs and the establishment of later dates for the acceptance of technical program papers, coupled with continuing severe printing congestion and other production problems, it became practically impossible to obtain and publish the abstracts in advance of the meetings. The change will improve this situation in part at least, because the new digests will be published in *ELECTRICAL ENGINEERING* more or less in the order of their receipt and availability, and the publication of and one group of digests relating to a given meeting will extend over several issues, thus relieving publication congestion and resulting in a better balance of subject matter.

Whereas the previous abbreviated abstracts were supposed only to give a brief insight into the content of the paper, supplementing its published title, the new digest will give much more information. Each author specifically will be requested to prepare his digest so as to present a brief statement of his problem or objective and to give a concise summary of his results or conclusions, touching upon significant methods, but omitting detailed proofs and other intermediate steps as a rule. In addition, the provision for the use of one or two illustrations will provide further opportunity for doing a thorough, if concise, job of presenting the real heart of each paper.

This change is a further step in the development of improved service through *ELECTRICAL ENGINEERING* to the more than 44,000 members and subscribers currently receiving copies each month. Thus, at least the essence of each technical program paper will appear in the magazine during the course of a year and will appear also in its annual index. In many instances, of course, the subject of a paper may be of sufficient timeliness and broad general interest that a much more comprehensive treatment in *ELECTRICAL ENGINEERING* will be warranted, either supplementing or supplanting the standard digest according to current controlling circumstances.

## Statistical Methods Subcommittee Plans Educational Program

Several years ago the Standards committee of the Institute authorized the formation of a subcommittee on the application of statistical methods, with the thought that the introduction of statistical methods into the Standards of the Institute would result in improvement of the Standards. W. P. Dobson (F '43), Hydro-Electric Power Commission of Canada, Toronto, Ontario, Canada, was appointed chairman and a number of experts in the application of statistical methods in the electrical industry were placed on the committee to assist the chairman.

A survey of the field by the subcommittee led to the conclusion that its first job was the education of engineers in the application of statistical methods to their daily problems and, as a consequence, a series of basic articles were prepared and were published in *ELECTRICAL ENGINEERING*. A special publication, "Statistical Methods in Quality Control," combining the 11 articles of this series into one convenient pamphlet was issued in January 1948. It is available from the AIEE order department, 33 West 39th Street,

### AIEE PROCEEDINGS

Order forms for AIEE *PROCEEDINGS*, and abstracts of the papers included, have been published in *ELECTRICAL ENGINEERING* as listed below. Each section of *PROCEEDINGS* contains the full, formal text of a technical paper including discussion if any, as it will appear in the annual volume of *TRANSACTIONS*. *PROCEEDINGS* are issued in accordance with the revised publication policy that became effective January 1947 (*EE, Dec '46, pp 576–8; Jan '47, pp 82–3*), and are available to AIEE Associates, Members, and Fellows.

| Meetings | Abstracts | PROCEEDINGS Order Forms |
|---|---|---|
| Winter | Jan '47, pp 84–93; Feb '47, pp 190–1 | Feb '47, pp 33A and 34A |
| North Eastern District<br>Summer General | Apr '47, pp 401–02<br>June '47 pp 607–14; July '47, p 708 | June '47, pp 55A and 56A |
| Pacific General<br>Middle Eastern District<br>Midwest General | Aug '47, pp 840–2<br>Sept '47 pp 925–7<br>Nov '47, pp 1125–8 | Dec '47, pp 55A and 56A |
| Winter ('48) | Jan '48, pp 76–87 | Apr '48, pp 49A and 50A |

New York 18, N. Y., at 70 cents per copy, 50 per cent discount to AIEE members.

The committee now is collaborating with the American Society for Quality Control, with a view toward having joint meetings and the presentation of papers at District meetings on the actual use of statistical methods in both factory control of the quality of products and applications in the electric utilities field. The plan is that these papers be presented as parts of sessions on various subjects. For instance, sessions devoted to wires and cables might include a paper on some application of quality control through statistical methods by a cable manufacturer, or a session devoted to communications problems would include a paper on some outstanding application in that field.

The thought behind all of this is that engineers, through lack of familiarity with statistical methods, may be failing to use a very valuable tool that requires no more knowledge of basic theory for its satisfactory use, than a user of electric meters might need to properly utilize those meters. It is the thought of the committee that quality control is becoming such an essential part of the electrical industry that every engineer should have some knowledge of it, whether or not he needs it in his immediate work. The committee would welcome suggestions as to papers from engineers now utilizing statistical methods in their work.

## Lamme Medal for 1947 Awarded to A. M. MacCutcheon

The Lamme Medal of 1947 has been awarded to AIEE Past President A. M. MacCutcheon (F '26) retired, Reliance Electrical and Engineering Company, Shaker Heights, Ohio, "for his distinguished accomplishments in the development of motors for industrial needs, notably in the steel industry."

The medal will be presented during the AIEE summer general meeting in Mexico City, Mexico, June 21–25, 1948. It has been awarded annually since 1928 by terms of a bequest of the late Benjamin G. Lamme, chief engineer of the Westinghouse Electric and Manufacturing Company, to an AIEE member "who has shown meritorious achievement in the development of electric apparatus or machinery." The medalist's biography appears on page 404.

## Additional Abstract Received for Great Lakes Meeting

The following abstract was received too late to be included with the Great Lakes meeting abstracts published in the March issue of *ELECTRICAL ENGINEERING* (*pp 265–6*). The AIEE Great Lakes District meeting, at which the paper abstracted will be presented, will be held in Des Moines, Iowa, April 1–3, 1948.

**48-105—Analysis of Unsymmetrical Induction Machines;** *K. Burian* (*M '47*). *30 cents.* The cross-field theory of the single-phase induction machine can be extended readily to the analysis of unsymmetrical 2-phase induction machines, such as the capacitor motor and the split-phase motor in which the windings are not in space quadrature. This extension is presented in this paper resulting in expressions which permit prediction of the performance of the unsymmetrical machine if its design constants are known. The method of this paper is illustrated by a numerical example of a motor, and the results obtained are contrasted with published data of the same motor. An equivalent circuit for the unsymmetrical machine is derived. This circuit is particularly useful if tabular methods for performance calculations are employed.

## Joint Subcommittees Complete Technical Subcommittee Listing

Previous issues of *ELECTRICAL ENGINEERING* have carried information regarding the new AIEE committee structure. An explanation of the main committee organization (*EE, Oct '47, pp 1006–11*), the list of officers and committees with their personnel (*EE, Oct '47, pp 1031–5*), the scopes and personnel of the power group subcommittees (*EE, Jan '48, pp 106–09*), and the scopes and personnel of the industry, communciation and science, and general applications group subcommittees (*EE, Feb '48, pp 203–06*), have been covered. The following lists the joint subcommittees of the Institute, and completes the technical subcommittee listing.

**1. Joint Subcommittee on Electronic Instruments (Joint with Electronics and Instruments and Measurements Committees)**

W. R. Clark, *chairman* — G. N. Mahaffey
J. G. Reid, Jr., *vice-chairman* — C. W. Martel
Rudolf Feldt, *secretary* — H. R. Meahl
H. W. Berry — David Packard
L. T. Bourland — T. B. Perkins
C. T. Burke — J. J. Slattery
C. C. Chambers — E. R. Thomas
D. C. Drake — J. T. Thwaites
G. V. Eltgroth — W. H. Tidd
D. B. Fisk — C. A. Tobias
W. A. Geohegan — V. Ulrich
E. R. Haberland — A. H. Waynick
G. B. Hoadley — W. A. Weiss
J. A. Hutcheson — A. J. Williams, Jr.
Eric Isbister — W. P. Wills

*Present Activities:*

1. Conducting a survey of instrument manufacturers to determine the need for electronic tubes with special characteristics.

2. Sponsoring an AIEE conference on electron tubes for instrumentation and industrial use.

(Note: At this conference, which is scheduled for Philadelphia, March 29–31, 1948, results of the survey mentioned in item 1 will be presented as well as other subjects pertinent to the use of vacuum tubes in industry.)

3. To solicit, review, and sponsor technical papers and reports on electronic instruments.

*Proposed Future Activities:*

1. Investigation of desirable characteristics for circuit components to be used in conjunction with vacuum tubes (that is, improved sockets, improved rheostats, and so forth).

2. Investigation of the need for definitions and standards pertaining to electronic instruments.

**2. Joint Subcommittee on Telemetering (Joint with Substation and Instruments and Measurements Committees)**

Telemetering is assigned primarily to the committee on instruments and measurements and handled by a joint subcommittee comprised of members of both the committee on substations and instruments and measurements. Telemetering problems in connection with automatic stations will be assigned by the chairman of the committee on instruments and measurements to members of the subcommittee who are also members of the substation committee. Telemetering problems of a more general nature will be assigned by him to members of both main committees and where the problem is simply measurements it will be assigned only to members of the committee on instruments and measurements.

*Scope:* Besides sponsoring AIEE papers, conference sessions, and technical sessions at AIEE general meetings, the principal task assigned this joint subcommittee is the revision of the October 1941 AIEE report "Telemetering, Supervisory Control, and Associated Circuits."

*Substation Appointees:*

George S. Lunge, *chairman* — M. W. Keck (representative, carrier current committee)
W. A. Derr — A. W. Peterson
W. L. Hiscox, *secretary* — J. H. Vivian
C. W. Winegartner

*Instruments and Measurements Appointees:*

P. A. Borden — E. E. Lynch
E. C. Brown — W. E. Phillips
C. K. Duff — A. R. Rutter
J. T. Logan — G. M. Thynell
N. H. Young

**3. Joint Subcommittee on Standard Frequency Bands and Designations**

*Scope:* To consult with various interested groups and recommend designated bands which conform, as closely as possible, with the desires and needs of the majority. A logarithmic system of bands seems to be indicated to break up this enormous range from a small fraction of a cycle per second to $10^{28}$ cycles per second or higher into bands which can be designated readily.

Thomas Spooner, *chairman* (representative, electronic standards subcommittee)
C. T. Burke (representative, instruments and measurements committee)
G. B. Ransom (representative, communication committee)
F. B. Silsbee (representative, ASA sectional committee *C58*)

**4. Joint Subcommittee on Nucleonic Instruments (Joint with Nucleonics and Instruments and Measurements Committees)**

*Scope:* Treatment of all matters pertaining to the design, construction, and application of devices used for the detection and measurement of nucleonic radiations. The activity of the subcommittee in this field will include:

1. Sponsorship of papers of two general kinds, namely, survey papers of a broad educational nature and descriptive papers covering developments primarily of interest to the membership.

2. Sponsorship of conference sessions on similar subjects.

3. Co-operation with the various existing committees of the AIEE and other organizations, particularly with respect to standardization and definitions. (In this latter instance, it is believed this subcommittee's efforts initially will be by way of review and suggestion.)

G. W. Dunlap, *chairman* — M. M. Hubbard
E. E. Goodale, *secretary* — J. A. Hutcheson
William E. Barbour, Jr. — P. S. Johnson
L. F. Curtiss — J. B. H. Kuper
F. J. Gaffney — Frank D. Lewis
W. H. Hall — G. A. Morton
M. A. Schultz

**5. Joint Subcommittee on Servomechanisms (Joint with Industrial Control, Instruments and Measurements and Basic Sciences Committees)**

J. B. Russell, *chairman* — S. W. Herwald
H. J. Marcy, *secretary* — Robert W. Hutchinson
E. R. Behn — Richard W. Jones (*IC*)
G. S. Brown (*IC*) — E. U. Lassen (*IC*)
E. D. Doyle (*IM*) — Everett S. Lee (*IM*)
M. A. Edwards — G. D. McCann (*BS*)
J. L. Fuller (*IM*) — M. Michel (*IC*)
D. E. Garr — S. J. Mikina
T. S. Gray (*IM*) — Carlton W. Miller

(*IC* indicates member of industrial control committees *IM*, member of instruments and measurement committee; *BS*, member of basic sciences committee.)

## Sections Committee Holds Business Meeting in Pittsburgh

With a recorded attendance of 55 persons, the AIEE Sections committee held a busy all-afternoon working session January 28, 1948, at the William Penn Hotel at Pittsburgh during the winter general meeting. Committee Chairman J. C. Strasbourger presided, and representatives were present from half of the Institute's 80 Sections, ranging from Massachusetts to the State of Washington, and from Michigan to Louisiana. President Blake D. Hull and Presidental Nominee Everett S. Lee, Secretary H. H. Henline, and a scattering of District officers also were present.

### AGENDA

The afternoon's discussions centered around the following official agenda, which indicates something of the scope and nature of the work to which the Sections committee currently is addressing itself:

1. Introduction of Sections committee members.
2. Proposed bylaws revision:
(*a*). Member of promotional group in each District to be a member of the District executive committee. (Bylaw Section 32)
(*b*). Change in number of members required to petition for Section status (25 to 40). Minimum membership of 25 to retain Section status. Minimum of 7 meetings per fiscal year. (Bylaw Section 36)
(*c*). Organization of Subsection (Division).
3. (*a*). Status of territory outside continental United States, Canada, and Mexico.
(*b*). Type of organization in these territories.
4. Sections committee meetings program for summer general meeting, Mexico City, June 21–25, 1948.
(*a*). Delegates get-together.
(*b*). Conference on Section operation and management (The "Ideal Section").
(*c*). Conference of officers, delegates, and members.
(*d*). Conference on formation of Subsections.
5. Prize paper awards.
6. The ideal or model Section. A résumé of all activities which contribute to the operation and management of a successful Section.
7. Other business.

Each of these various topics brought forth a wide variety of opinions and comments which, in most instances, were rationalized through the medium of extended discussion. The several recommendations for changes in the bylaws were passed along to the board of directors for further discussion and consideration.

To study the various administrative, operational, and policy questions involved incidental to the formation of Subsections or Divisions outside the continental United States, Canada, and Mexico, action was taken establishing a special subcommittee of the Sections committee. The personnel of this subcommittee have not been announced as yet. The popular success of the various conferences held in Montreal during the 1947 summer general meeting under the auspices of the Sections committee led the committee to take formal action authorizing the same type of program on Section matters to be set up for the forthcoming summer general meeting in Mexico City.

General discussion of the subject of AIEE prize awards for technical papers, led to a formal action establishing a subcommittee for the purpose of making a comprehensive study of all aspects of that subject. The following committee was appointed on the spot:

F. S. Black of the Washington Section, *chairman;* D. I. Anrini of the San Francisco Section; G. W. Bower, AIEE vice-president for the Middle Eastern District; Victor Siegfried, secretary North Eastern District and nominee for member of the board of directors; E. W. Stone of the Illinois Valley Section.

Also, it was suggested specifically that Lloyd F. Hunt of the Los Angeles Section and Chairman H. M. Turner of the AIEE technical program committee be asked to give assistance and co-operation to the committee in its project.

On the subject of allocation of Section territory, the actions taken were:

1. Voted to recommend to the board of directors the reallocation of the State of New Hampshire to the Boston Section, "for the purpose of promoting more extensive AIEE activities in the extreme northeastern portion of the United States."
2. Voted to recommend to the board of directors the reallocation of Harrison and Jefferson Counties in the State of Ohio to the Canton Section, "to enhance the further development of AIEE activities in Ohio."
3. Voted to recommend to the board of directors the reallocation of the territory of Alaska to District 9, and specifically to the territory of the Seattle Section.

Considerable discussion was devoted to the project of attempting to develop something of a set of specifications for a "model Section," by means of which the relative effectiveness and efficiency of different Sections and Section programs, large or small, might be evaluated fairly and compared for administrative and developmental purposes. No action was taken, but it is to be expected that further consideration will be given to this topic.

4. Pursuant to recommendations received from the executive committee of the North Eastern District, authorized the appointment of a subcommittee of the Sections committee "to study the whole question of Section and Institute finances and to present recommendations back to the Sections committee for transmittal to the Institute's finance committee," toward the general hopeful objective of "an increase in the yearly Section allotments to permit increased Section activity at the present level of costs, such increase to be directed toward encouraging and expansion of the technical program of the Section and to be effected without resulting in an increase in membership dues." The committee, appointed on the spot, includes:

Victor Siegfried of the Worcester Section, *chairman;*
F. S. Black of the Washington Section
C. W. Lethert of the Minnesota Section
C. W. Mier of the Dallas Section
H. W. Sussman, secretary of the Sections committee
F. G. Webber of the Springfield (Mass.) Section.

Among the various other topics relating to Section activities which were discussed were: Section meetings, administrative, general, and technical groups; publicity; membership and transfers; awards; Student activities; Section developments; educational courses; local technical councils.

## New Subcommittee Formed to Study Probability Methods

The AIEE technical committees on power generation and on system engineering have announced the formation of a joint subcommittee on probability methods. G. Calabrese (M '40) of the Consolidated Edison Company of New York, Inc., New York, N. Y., has been designated chairman and the personnel are in the process of appointment.

The idea for the subcommittee originated with the presentation of four papers on probability at the AIEE Midwest general meeting in Chicago, Ill., in November 1947. These papers were the following:

"Generating Reserve Capacity Determined by the Probability Method" (47-248) by G. Calabrese.

"Calculating Probability of Generating Capacity Outages" (47-252) by W. J. Lyman.

"Outage Expectancy as a Basic for Generator Reserve" (47-253) by H. P. Seelye.

"Probability Methods Applied to Generating Capacity Problems of a Combined Hydro and Steam System" (47-254) by E. S. Loane and C. W. Watchorn.

Probability methods for studying generating capacity, outage expectancy, reserve requirements in transmission, transformation, and distribution facilities will be included in the committee scope.

## Future AIEE Meetings

**AIEE Conference on Electrical Engineering Aspects in the Rubber and Plastics Industries**
Auditorium of M. O'Neil Company Department Store, Akron, Ohio
April 20, 1948

**Great Lakes District Meeting**
Des Moines, Iowa
April 1–3, 1948
(*Final date for submitting papers—closed*)

**North Eastern District Meeting**
New Haven, Conn.
April 28–30, 1948
(*Final date for submitting papers—closed*)

**Summer General Meeting**
Palace of Fine Arts, Mexico City, Mexico
June 21–25, 1948
(*Final date for submitting papers—closed*)

**Pacific General Meeting**
Spokane, Wash.
August 24–27, 1948
(*Final date for submitting papers—June 10*)

**Middle Eastern District Meeting**
Hotel Statler, Washington, D. C.
October 5–7, 1948
(*Final date for submitting papers—July 21*)

**Midwest General Meeting**
Schroeder Hotel, Milwaukee, Wis.
October 18–22, 1948
(*Final date for submitting papers—August 3*)

**AIEE Conference on Electronic Aids to Medicine**
New York, N. Y.
Fall, 1948

**Southern District Meeting**
Birmingham, Ala.
November 3–5, 1948
(*Final date for submitting papers—August 20*)

**Winter General Meeting**
Pennsylvania Hotel, New York, N. Y.
January 31–February 4, 1949

# Preliminary Plans Progress for Summer General Meeting in Mexico City

Plans currently under way for the 1948 summer general meeting in Mexico City, June 21–25, give all indication that this year's meeting will be long remembered, both for the interest of its technical program, and for its colorful and picturesque meeting site. Not only are the problems of a country undergoing industrialization of great technical interest, which will provide material for lively technical sessions and a variety of inspection trips, but every opportunity will be provided to take advantage of Mexico's facilities for sightseeing and recreation, to make the summer meeting an exciting vacation. In relation to plans for the meeting, as reported elsewhere in these pages, C. S. Purnell, chairman of the AIEE special meeting committee, recently spent a week in Mexico City in direct conference with the local general meeting committee there, working out many of the administrative and operational details in preliminary to the summer meeting.

### REQUEST-FOR-INFORMATION COUPON

The special meeting committee in New York is processing the request-for-information coupons already returned to headquarters, and inquiries very soon will be receiving the requested information. Any persons possibly interested in attending the meeting should fill out and return the coupon immediately to receive full information on the various methods of reaching Mexico City, sightseeing trips, hotels, and so forth. The coupon appeared in the February issue of *ELECTRICAL ENGINEERING* on page 56A of the advertising section, and in the March issue on advertising page 58A.

### REQUIREMENTS FOR CROSSING THE BORDER

Requirements to enter Mexico from the United States are both few and simple. No passport is needed to enter Mexico City for a stay of less than six months by tourists or students, where no business is involved. Mexican tourist cards are needed, however, which can be procured from any Mexican consulate for the fee of $2.10. Proof of United States citizenship, such as a birth certificate, is required. Application for a tourist card may be made either in person or by mail to the nearest Mexican consulate. Mexican consulates are located in the United States as follows:

Arizona—Douglas, Naco, Nogales, Phoenix, Tucson

California—Calexico, Fresno, Los Angeles, San Bernardino, San Diego, San Francisco, Santa Ana

Colorado—Denver

District of Columbia—Washington

Florida—Miami

Illinois—Chicago

Louisiana—New Orleans

Massachusetts—Boston

Michigan—Detroit

Missouri—Kansas City, St. Louis

New Mexico—Albuquerque

New York—Buffalo, New York

Ohio—Cleveland

Oklahoma—Oklahoma City

Oregon—Portland

Pennsylvania—Philadelphia, Pittsburgh

Texas—Alpine, Austin, Brownsville, Corpus Christi, Dallas, Del Rio, Eagle Pass, El Paso, Fort Worth, Galveston, Houston, Laredo, McAllen, San Antonio, Zapata

Utah—Salt Lake City

Virginia—Norfolk

Wisconsin—Milwaukee

Tourist cards also may be obtained at American Airlines' offices or at the border.

### VACCINATION CERTIFICATES

It would be worth-while, in the interest of convenience if nothing else, for the traveler to have a valid and up-to-date smallpox vaccination certificate in his possession before crossing the border southward bound into Mexico. A smallpox vaccination is officially rated as being valid for a period of three years from the date of vaccination, so that all that a great many persons would have to do would be to be sure that they have their certificates in their possession. No certificate is necessary to enter Mexico, but persons attempting to re-enter the United States without the required smallpox vaccination certificate will find themselves confronted with some additional delay and paper work at the border where they probably will be placed under technical surveillance and then allowed to proceed to their home destinations subject to the requirement that they report in person to their local public health officer within two weeks after returning home; the United States Public Health Service in the meantime having given such local public health officer official notification of the provisional quarantine placed upon the traveler, with the full weight of United States laws and substantial penalties backing up the requirements for the report to the local health officer by the individual traveler. Thus, it is not necessarily impossible for a visitor to enter Mexico and return without the smallpox vaccination certificate, but it would be very much more convenient for him to obtain it first, from his own doctor.

### ADVANCE HOTEL RESERVATIONS

Members and friends intending to go to Mexico City for the annual summer general meeting should make, without exception, specific hotel reservations several weeks in advance, to allow for individual confirmation of those reservations before setting out to travel to Mexico City. C. S. Purnell, of the New York Section, chairman of President Hull's special meeting committee charged with the responsibility of co-ordinating the plans and activities of the summer general meeting recently returned from a week spent in Mexico City in a series of conferences with the local general meeting committee operating there under the chairmanship of Oscar Enriquez of the Mexico Section. Mr. Purnell brought back the following information with reference to hotels.

To be assured of an adequate number of rooms in the better hotels located most conveniently with reference to the Palace of Fine Arts where most of the technical sessions will be held, definite arrangements have been made to concentrate AIEE members and their guests from the United States and Canada among the following major hotels: Del Prado, Regis, Prince, Reforma, and Geneve. All reservations will be handled by the Mexico Section's local hotel committee and any individual reservations made directly with the hotels will be referred by the hotels to the committee for co-ordination. It is important that members understand this procedure, because by far the major portion of the available space in each of these hotels already has been assigned specifically to this hotel committee for the benefit of AIEE members for the week of June 21,

**Arch of the Revolution, Mexico City**

leaving only very limited facility for persons not specifically identified with AIEE.

Members should make hotel reservation requests by writing direct to the "Hotel Reservation Committee," AIEE 64th Summer General Meeting, Palma 33, Despachio 210, Mexico, D. F., Mexico. This committee will assign hotel space to American and Canadian members and their guests, as nearly as possible in accordance with the expressed preferences which accompany the reservation requests. The rates for hotel rooms in the listed hotels will range from approximately $5 to $10 for a single room, and from $8 to $14 per day for a double room (in terms of United States dollars). Members should express their preference for single room, double room, or parlor suite, and also should indicate the approximately range or preferred limit of desired room rate. Early action in making reservations is essential, and will help the committee to carry out its work most satisfactorily.

## Mexico Section Host to AIEE Delegate

Incidental to his week's visit in Mexico City on official AIEE business relating to the forthcoming summer general meeting there, C. S. Purnell of the New York Section, chairman of President Hull's AIEE special meeting committee, was featured as the honor guest of the Mexico Section at a special dinner meeting at the American Club, February 25. Mr. Purnell addressed the Section gathering on the general subject of the summer meeting, explaining the nature of his visit to Mexico for the purpose of correlating with the local committee the rapidly progressing arrangements for the June meeting, and for the purpose of acquiring first-hand information for direct dissemination to interested AIEE members elsewhere in the United States and Canada. He congratulated the Mexico Section upon the magnitude and strength of its growth as an AIEE Section, and touched upon the significance of the forthcoming summer general meeting as something of an international joint congress of American, Canadian, and Mexican engineers mutually interested in the technical and engineering progress in Mexico, Canada, and the United States. He expressed the view that a first-hand exchange of ideas through the medium of such a meeting could and should do much to bring about a closer understanding and relationship of mutual advantage to all concerned, and a further step in the consolidation of mutual interest in the Western Hemisphere.

About 180 persons were gathered at the American Club for this meeting of the Mexico Section, for which General Electric S. A., was the host. A technical presentation of considerable interest was given by Señor Martinez of that company on "Packaged Hydroelectric Power Plants."

Mr. Purnell brought back first-hand information on the summer meeting which is reflected elsewhere in these columns.

# A Message From the Mexico Section

**Oscar R. Enriquez**

Among today's world-wide organizations there is none that enjoys a greater prestige than the AIEE. As a technical organization it can boast of being the largest with 28,000 active members spread throughout 70 different countries. Although most of its membership is found in the United States, its important Tenth District is located in the Dominion of Canada, and in Mexico we have our Mexico Section. More than 4,000 members of the Institute reside outside the United States, and as a consequence our organization enjoys an enviable international reputation. Even in such countries as do not maintain large membership, we have prominent resident engineers acting as honorary secretaries. In this way, the Institute constantly is growing and extending its influence abroad.

Although various meetings have been held in Canada, the first one to be scheduled for Mexico will be our 64th summer general meeting this coming June. This concretely attests to the international character of the Institute.

The basic principles upon which the Institute is founded dedicate it to the advancement in theory and practice of electrical engineering and all related arts and sciences. The high sense of profesional responsibility existing throughout its membership assures the progress and development of the electrical industry over the entire world. There is no doubt in the minds of the Mexican members of the AIEE that our Institute has a splendid future, and we believe the time is near when every electrical engineer will seek membership in our great organization.

The 64th summer general meeting to be held in Mexico, June 21 to 25, is a serious step toward uniting more closely the electrical engineers of the Western Hemisphere. Mexico is the geographical connecting link between North and South America, and thus there is every reason to believe that this effort to achieve the union of engineers of all the nations of the Continent will be eminently successful. We Mexicans look forward to co-operating with engineers from both north and south, a happy opportunity which is heightened by this meeting in Mexico. The interchange of technical problems thereby afforded, and the facility for meeting one another, will be of tremendous value and will contribute to the progress of our work in each of the countries represented, because basically this depends upon the correct solution of technical problems connected with the exploitation of natural resources, the manufacture of products required for subsistence, and the production of articles contributing to comfort and welfare. Furthermore, we believe that inasmuch as electrical engineering is indisputably one of the greatest contributing factors to human progress, the future of the nations of our Continent will benefit immeasurably by discussions of mutual technical problems which, in turn, will establish a closer understanding and a heightened mutual esteem.

The Mexican engineers entrusted with the organization of the 64th summer general meeting are mindful of the fact that the many AIEE members and guests who will attend this meeting will be confronted with considerable competition for their interests, between the program of excellent technical sessions and special features being arranged and the many features of technical and human interest to be found here in Mexico. Also, there has been the problem of adjusting both the social and the technical features of the program so as to harmonize on the one hand with the facilities, habits, and customs of the Mexican people, and on the other hand with the tastes and interests of our expected visitors. Accordingly it has been arranged that there will be no conflict between the two major parts of the program. All excursions, technical visits, entertainments, and sports will take place in the mornings and until noon. Originally it had been suggested by our local committee that the most important part of the program, the presentation and discussion of technical papers, should begin at 6 p.m. (18 o'clock Mexico City time), but to enable all delegates to participate at these conferences, the executive committee charged with arranging the program responded to the request from AIEE headquarters for an earlier hour, and arranged for the technical sessions to begin at 4 p.m. (16 o'clock Mexico City time) and to continue to 6:30 p.m. (18.30 o'clock Mexico City time).

In conclusion, as the chairman of the summer general meeting committee, and in the name of all the members of the Mexico Section, I take pleasure in extending by these means and through the courtesy of *ELECTRICAL ENGINEERING* a most cordial and sincere invitation to every member of our Institute to contribute to the success of this international event by taking advantage of this opportunity to visit and know Mexico, and by partaking of her traditional hospitality.

**Oscar R. Enriquez** (M '46), head of the office, hydroelectric division, Comision Nacional de Irrigacion, Balderas, Mexico, Federal District, Mexico, is chairman of the 64th summer general meeting committee.

# AIEE Membership Committee Meets During Winter Meeting

An open meeting of the AIEE membership committee was held January 28 at the William Penn Hotel in Pittsburgh during the 1948 winter general meeting for the purpose of reviewing membership objectives, activities, and procedures. In addition to Chairman Tomlinson Fort (Pittsburgh), Vice-Chairman F. S. Black (Washington, D. C.), and Secretary F. A. Norris (AIEE headquarters, New York), the 40-odd persons who attended and took part in the conference included President Blake D. Hull and Presidential-Candidate Everett S. Lee; also, vice-presidents or District secretaries representing five Districts, in addition to five out of the ten District vice-chairmen of the membership committee; eight of the 21 members-at-large of the membership committee, and chairmen or membership chairmen representing ten local Sections; the chairman and secretary of the AIEE Sections committee.

This group spent a busy 3-hour session listening to and discussing the various comments and suggestions embraced in informal addresses on the following topics:

1. Attracting members in a metropolitan area, presented by Vice-Chairman F. S. Black of the membership committee.

2. Attracting members outside metropolitan areas, presented by W. S. Leake, member-at-large of the membership committee from New Orleans, La.

3. Securing our most important prospect—the recent graduate, presented by Stanley Tucker on behalf of R. F. Ham, member-at-large from New York City.

4. Membership activity—its place in Section operation, presented by J. F. Strasbourger of Cleveland, chairman of AIEE Sections committee.

5. Organizing membership activity on a District basis, presented by J. C. Woods of Chicago, vice-chairman of the membership committee for the Great Lakes District.

6. The AIEE membership committee—its operation and objectives, presented by Chairman Tomlinson Fort.

Chairman Fort quoted from AIEE bylaws for the purpose of refreshing the memory of all concerned with reference to the charge of opportunity and responsibility given to the AIEE membership committee: "This committee shall bring the advantages of membership to the attention of desirable candidates for admission to the Institute, through such measures as it may consider advisable to interest prospective members who have the standing and qualifications specified for the various grades of membership..." pointing out that although AIEE is growing steadily and strongly, "...it is estimated that not nearly half of the eligible electrical engineers of the United States are members of AIEE." "The electrical engineering profession is one of great accomplishment and great promise, we best can develop its potentialities by building an even stronger American Institute of Electrical Engineers. This cannot be done unless we have the members...."

In response to a request for comment, President Hull expressed his belief that the increasing interest in the organization of Subsections where needed to serve interested members effectively, would be of direct aid to the committee in obtaining new members from the estimated 50 per cent of persons identified with the electrical profession who are not Institute members. He also expressed his strong belief in the importance of the meetings programs of Institute Sections, stating that they must be of an interesting and constructive nature to attract or hold qualified members. Mr. Lee, who is past chairman of the membership committee, strongly seconded President Hull's comments, emphasizing the desirability and importance of a mutual and sympathetic understanding of membership committee problems and objectives by the chairmen of local Sections, the District officers of the Institute, and AIEE Sections committee.

It is expected that the pertinent substance of the afternoon's discussions will be disseminated through appropriate committee channels.

## Basic Sciences Committee Meets During Winter Meeting

A meeting of the committee on basic sciences was held Tuesday morning at 10 a.m. during the AIEE winter general meeting in Pittsburgh, Pa. Plans for future technical meetings of the Institute were discussed and it was agreed that the committee on basic sciences had no particular assignment for the Mexico City meeting, but that efforts should be concentrated on the Fall 1948 and Winter 1949 meetings.

The subcommittee on energy sources is planning to continue its program of reviewing its field, in which two conferences already have been held. The Milwaukee meeting in October 1948 will include the presentation of papers on conversion of electric energy from one form to another form, atmospheric electricity, and terrestrial electricity, while at the 1949 winter meeting the plans are for consideration of animal electricity, including the consideration of nerve action.

New subcommittees were authorized to study the fields of the electrical properties of solids, liquids, and gases, and to investigate the many phenomena in the realm of magnetism. Suggestions of membership of these new subcommittees were requested from the committee members.

The subcommittee on applied mathematics will endeavor to arrange a joint program with the American Mathematical Society for both AIEE and AMS meetings. At the present technical meeting a conference was held on "What the Engineer Can Do With His Experimental Data."

The almost complete lack of definitions in the field of electric circuit theory has led the subcommittee assigned to the subject to prepare a comprehensive list of terms to be defined. It is planned to complete this list in co-operation with other societies, with the ultimate aim of introducing them into the revised "American Standard Definitions of Electrical Terms."

As the chairman and several members of the committee on basic sciences are also members of Subcommittee 1 of the American Standards Association Sectional Committee C 42 which is revising the "American Standards" a meeting of Subcommittee 1 was held immediately following the basic sciences discussions. Considerable work has been done by the members of this subcommittee on the revision of the fundamental and derived terms (group 05) and it was agreed that reviews of these proposed definitions will require more frequent meetings from now on.

## Transmission and Distribution Discussed on Wednesday

C. F. Wagner (F '40) Westinghouse Electric Corporation, East Pittsburgh, Pa., presided on Wednesday at a session on transmission and distribution. Four technical papers were on the program for the session.

### LARGEST SERIES CAPACITOR

The largest power and high-voltage series capacitor in the world was installed recently on a 66-kv line of the Duquesne Light Company to eliminate a large part of the lamp flicker resulting from an electric furnace load. The installation, design, and protection, were described in three papers: "A 10,000-Kva Series Capacitor Improves Voltage on 66-Kv Line Supplying Large Electric Furnace Load" (48-55), by B. M. Jones (F '42), J. M. Arthur (A '45) and C. M. Stearns, all of the Duquesne Light Company, Pittsburgh, Pa., and A. A. Johnson (M '44) of the Westinghouse Electric Corporation, East Pittsburgh, Pa.; "Design and Layout of 66-Kv 10,000-Kva Series Capacitor Substation" (48-56), by G. B. Miller (M '46), of the Duquesne Light Company, Pittsburgh, Pa.; and "Design and Protection of 10,000-Kva Series Capacitor for 66-Kv Transmission Line" (48-57), by A. A. Johnson, R. E. Marbury (F '45) of the Westinghouse Electric Corporation, East Pittsburgh, Pa., and J. M. Arthur. Several methods of minimizing voltage fluctuation were considered, but the series capacitor seems to be the most economical and satisfactory. Calculations were given to show that three banks of 2,400-volt 15-kva capacitors in series were needed. To supply the necessary 500-ampere rating, 80 units in parallel constituted each bank, thereby providing 14.4 ohms impedance for the three groups in series. After considering several alternatives, it was decided to shunt the capacitor bank with a 400-ohm

resistance to avoid ferroresonance and self-excitation of induction motors and synchronous motors with induction starts. Tests of the line in operation proved that the calculations and predictions were well founded. A more complete report of these papers appeared in the March issue (*EE, Mar '48, pp 236–41*).

TRANSIENT SHAFT TORQUES

"Transient Shaft Torques in Turbine Generators Produced by Transmission-Line Reclosing" (48-25), by J. W. Batchelor (M '47), D. L. Whitehead (A '41), and J. S. Williams (A '41), of the Westinghouse Electric Corporation, East Pittsburgh, Pa. A calculating method applicable to the a-c network calculator has been devised for determining the torque resulting from closing lines with various synchronizing angles. Although in present installations this torque is generally less than that which the generator was designed to withstand, a quantitative check on future installations is desirable. Single-pole tie line reclosing seems to be the most practical in maintaining system stability with single tie lines.

## City Transit Dominates Light Traction Discussion

A session on light traction was held on Wednesday, January 28, under the chairmanship of J. C. Aydelott (M '32) General Electric Company, Erie, Pa. Of the four technical papers on the session's program, three considered vehicles on various city transportation systems.

DISTRIBUTION CIRCUITS

A simplified method has been developed for calculating the design and layout of d-c distribution circuits and was described in "Trolley Coach Distribution System" (48-63), by G. R. McDonald (A '21) of the General Electric Company, Erie, Pa. By this method, feeder arrangement, feeder copper, and other factors are laid out to take care of peak conditions through the use of a diversity curve based upon trolley-coach maximum current demand. A sample design calculation was given, followed by explanation and comment of the procedure to be followed on typical problems which arise.

ECONOMIES

G. M. Woods (M '43) of the Westinghouse Electric Corporation, East Pittsburgh, Pa., next presented his paper entitled "Electrically Propelled Vehicles Most Economical in City Transit" (48-62). A comparison of trolley coaches, streetcars, and motor busses reveals that the greater the density of passenger traffic, the greater the advantage of electrically propelled vehicles. The dividing line between economical use of the streetcar and the trolley coach was given as 2,500 passengers per maximum hour, although it was pointed out that each system must be designed with the individual application in mind.

NEW RAPID TRANSIT CAR

A new vehicle for use in elevated and subway service which incorporates many of the standard Presidents' Conference Committee streetcar components was described by H. A. Otis of the Chicago Transit Authority, Chicago, Ill., in his paper "Three-Compartment Articulated Cars for Test on Rapid Transit Division, Chicago Transit Authority" (48-64). This is one of four cars to be tested comparatively. The car has three articulated bodies mounted on four trucks and weighs 93,000 pounds. Its seating capacity is 96 and its total capacity is 250. The lighting, heating, ventilating, door control, trucks, motors, motor controls, and braking were described in the presentation.

RAILROAD CARS

The trend toward lightweight passenger cars has motivated a change to "A-C Air Conditioning for Railroad Passenger Cars" (48-51), which was described by H. H. Hanft, of the Westinghouse Electric Corporation, East Pittsburgh, Pa. A single complete refrigerating system was described consisting of six component parts. Two hermetically sealed compressors having a total cooling capacity of eight to ten tons are driven by 5-horsepower 3-phase 60-cycle 220-volt 1,750-rpm squirrel-cage induction motors. The condenser is of the conventional thin copper tube construction and is carried under the car in a separate compartment. The evaporator package is mounted overhead in the car and consists of a blower unit, an evaporator, and an electric strip heater assembly with optinal methods for cleaning ventilating air and air recirculation. The power control panel is mounted in the car body, and its contactors are under the control of heating and cooling thermostats sensitive to inside and outside temperatures. Voltage control for the overhead electric heating element is supplied by a selenium battery-charging rectifier and the saturable core reactor. Two master thermostats are used to provide automatic changeover from heating to cooling and to reduce excessive humidity in the car on cool humid days without the use of controls actuated by the mositure content of the car air. Inherent freedom from maintenance and liability to failure is a prime advantage of this system. Weight reduction achieved by smaller battery sizes, smaller power cables, and the elimination of parasitic axle drag on the locomotive also are advantages of this system.

## History and Application Covered of Copper Oxide Rectifiers

An interesting group of six papers, five of which were the conference type of paper, covering the history, development, and present-day application of copper oxide rectifiers, was presented at the session on metallic rectifiers, Thursday morning, during the AIEE winter general meeting in Pittsburgh, Pa. L. O. Grondahl (F '47) of the Union Switch and Signal Company, Swissdale, Pa., well known for his work in the copper oxide rectifier field, presided over the session.

METHOD OF MANUFACTURE

A conference paper on "Mechanized Methods of Manufacture of Copper Oxide Rectifiers," was presented by E. A. Harty (M '36) General Electric Company, Lynn, Mass. A very interesting motion picture film called "Stacks of Power" was shown during this talk. In the motion picture the process by which copper oxide rectifiers are manufactured in traced from the laboratory through the manufacturing process in the plant. Included were representative pictures of such items as characteristics of the rectifier cell, microscopic and spectroscopic tests showing analysis of a copper sample, various manufacturing tests made in the pilot plant, and finally the actual manufacturing process itself. The first operation is the blanking of the copper to the desired shape, the next is to clean chemically the surface of the copper, blanks then are air-dried, heated to produce an oxidized surface, annealed, the black oxide is removed from a portion of the plate to assure good electric contact, electric contact area on the oxide surface is formed by nickel plating, excess nickel then is removed, and then the disk is ready for assembly. During the manufacturing process a close quality control check is maintained. Among the quality controls checks made are such items as checking samples of copper melts, furnace temperatures are recorded, solutions are checked and titrated, the cells are tested electrically, the completed stack assemblies are inspected, the individual cells in the stack assembly are checked, a high potential test of the completed stack is made, and the over-all output test of the stack is made also. It was interesting to note that all critical operations in the manufacturing process have been mechanized. It was pointed out that the copper oxide rectifier business in 25 years has grown from a $50,000 business to one running into millions of dollars.

INDUSTRIAL APPLICATIONS

"Industrial Applications of Copper Oxide Rectifiers," was discussed by I. R. Smith (A '43) Westinghouse Electric Corporation, Buffalo, N. Y. This paper briefly discussed the development of the rectifier into the power and industrial fields. Power applications began commercially in 1926, with a small radio *A*-battery charger, rated one-half ampere at 6 volts, or 3 watts output. This small unit was contrasted with one that was manufactured in 1947 which had a continuous rating of 16,700 amperes at 6 volts, 100,000 watts. These two units were said to cover the range of ratings that have been developed during the years between. During the first few years of rectifier development there was a rapid increase in power output until about 2-kw output was

reached. This was an approximate ceiling for self-cooled rectifiers. With the advent of forced cooling, quantities of rectifiers in the 2- to 3-kw range were produced, but there was a limit imposed by the use of small disks, even though fan-cooled. Development of plate-type units, starting in about 1935, was responsible for the later increases in power output which finally reached 100 kw of continuous output from a single rectifier unit. Of course installations have been made grouping a large number of rectifiers, such as, for example, the continuous tin plating lines where a single line may use typically 120,000 amperes at 6 volts, or 720 kw. After the 3-watt rectifier was developed in 1926, people began to consider the rectifier for such uses as excitation of dynamic speakers, *B*-eliminators, electric hammers, industrial control and brakes, business machines, fire alarm chargers, and communication work. Soon applications were made in the field of cathodic protection and circuit breaker operation. In 1930 instrumentation applications began to appear. Fan-cooled units were used in large quantities in 1935 for motion picture arc projection. A year later plate rectifiers entered the electric plating field. In 1939 a large fast charger market made its beginning, also high-voltage types were used in radiobroadcasting. By 1940, rectifiers branched out into welding, charging of railway batteries, and anodizing of aluminum. In 1943 a peak was reached in the building of tin plate lines. Slides were shown which illustrated the various types and sizes of rectifiers that were being mentioned. It was pointed out that in some applications these rectifiers are used at high voltages, one of the slides illustrating a totally enclosed unit, rated at 70 kv, and one-quarter of an ampere, which is used for fly ash precipitation.

### RAILWAY SIGNALING

"Copper Oxide Rectifiers in Railway Signaling," was discussed by G. W. Baughman (M '45) Union Switch and Signal Company, Swissvale. This paper made reference to the first installation where practical use was made of the copper oxide rectifier. This was the initial train control installation on the Lackawanna Railroad, the territory from Buffalo to Elmira, N. Y., on which construction work was started during the year 1924. The purpose of this rectifier was to accept alternating current from the secondary of the output transformer of the vacuum tube amplifier, which was carried aboard the locomotive, and to deliver direct current to a relay, the contacts of which control the cab signal. It was on this original installation that practical experience indicated the necessity of maintaining the pressure against the copper oxide surface. The next application, and the one accounting for the greatest number of rectifiers used in railway signaling, was for the charging of line and track storage batteries. The many advantages of the copper oxide rectifiers over other rectifiers in the field caused it to receive immediate and varied general acceptance. Power for the signal system when the trickle charge method was used is purchased economically from towns along the railroad. The batteries can be on continuous trickle charge so that energy is available to maintain operation of the signal system even though the a-c source of power should fail. The use of rectified power with batteries for standby is now almost universal for railway signal systems. Retaining the same general system, some railroads prefer to use primary batteries instead of storage batteries, and in this instance a rectifier may be connected so the primary battery is "floated" and normally very little energy is taken from the primary battery. Reports from service indicate that primary batteries used in this manner will have a life approximately ten times greater than if the rectifier were not used. The so-called automatic rectifier makes use of the saturable core principle, so the rectifier supplies a current varying directly with the load connected to the battery, thus bringing about a still greater increase in primary battery life to approximately 20 times greater than if no rectifier were used. The signal systems in the subways of New York, Philadelphia, and Chicago are outstanding examples of important signal installations in service where the source of a-c power and the design of distribution systems are so reliable that the rectified energy is used directly for the operation of d-c signal systems. Another very important application of copper oxide rectifiers is in locomotives carried cab signal equipment. The general principles for coded cab signaling have been incorporated in several thousand cab signal equipments. It is interesting to note in this connection that the copper oxide rectifiers in a modern cab signal system account for less than one per cent of the cost of the locomotive carried equipment, yet they form an indispensable part of the system. Another well-known application of copper oxide rectifiers is in the protection of contact operating conductive d-c circuits, as well as providing for a slow release for d-c relays. These principles are used extensively in the line, coding, and storage units of centralized traffic control systems. It was pointed out that in many years of service the copper oxide rectifier has proved itself to be a very versatile component of railway signal systems, with a length of life and ruggedness consistent with the requirements of that service.

### INSTRUMENT APPLICATIONS

Instrument applications were covered in a paper called "Copper Oxide Rectifiers in the Instrument Field," by F. X. Lamb (M '44) Weston Electric Instrument Corporation, Newark, N. J. This paper outlined the development of instrument rectifiers using copper oxide elements, and a number of examples were cited. It was pointed out that though a large number of instruments using this type of rectifier had been sold, not one case of a failure of the rectifier had been reported. It was pointed out that copper oxide rectifiers are rugged, they can stand fairly large overloads, they are adapted easily to use in instruments because of their small size, and that the copper oxide rectifiers are very reliable in use.

### COPPER OXIDE VARISTORS

Some applications of copper oxide rectifiers to communication circuits were discussed in the paper "Copper Oxide Varistors in Communication Circuits," by N. Y. Priessman, Bell Telephone Laboratories, New York, N. Y. The nonlinear characteristics of copper oxide rectifiers were discussed and their applications in the communications field. The use of copper oxide elements in modulation circuits also was covered.

### HISTORY

The session was opened by Chairman L. O. Grondahl presenting his paper "Twenty-Five Years of Copper Oxide Rectifiers" (48-66). Although the session was dedicated to the celebration of the 25th anniversary of the origin of the copper oxide rectifier, it was pointed out that this is an average between the discovery 27 years ago and the first practical use 23 years ago. The accidental discovery of the rectifying property of copper oxide was made during a search for a suitable relay without moving parts which could be substituted for the electromechanical relay then used in railway signaling. Although the theory of the rectifying characteristic of a copper–cuprous oxide junction has not been agreed upon, the physical properties of such a junction were enumerated and discussed. Practical developments in methods of production, research, testing, and utilization were given. Several characteristic curves were presented.

## Conference Held on Applied Mathematics

What the engineer can do with his experimental data was discussed at the January 29 conference sponsored by the applied mathematics subcommittee of the basic science committee. After a few introductory remarks by the chairman of the session, M. G. Malti (M '45) of Cornell University, Ithaca, N. Y., H. Poritsky, of the General Electric Company, Schenectady, N. Y., was introduced. He discussed one of the methods which is available for obtaining a maximum amount of information out of a minimum number of tests for functions which depend on many variables. This method, "Graeco-Latin squares," was explained briefly and experience in its use on several engineering problems was discussed. One of these problems related to an electric instrument; the other was a metallurgical problem of finding the optimum composition of an alloy.

E. G. Olds and Foreman Acton, Carnigie Institute of Technology, Pittsburgh, Pa., then spoke on the combination of observations and fitting of curves.

### DIMENSIONAL ANALYSIS

The foundations of dimensional analysis were discussed by Garrett Birkhoff, of Harvard University, Cambridge, Mass. It was shown that Buckingham's pi theorem can be proved without any restrictions on

the nature of the functions involved. Because the usual proofs assume that these functions can be expanded in power series, and in many applications this assumption is not fulfilled, this generalization seems worthwhile. Further, the assumption of differentiability in Bridgman's characterization of homogeneous variables by the property of "absolute invariance of relative magnitude," can be replaced by a weak continuity assumption.

Dimensional analysis can be applied to problems whose formulation is invariant under a group of transformations of the form $q_i \mapsto \lambda_i q_i [i = 1 \ldots n]$, permitting ordinarily a reduction by $n$ in the number of variables or parameters which need be considered. It was shown that this is true of any group, and that the same principle can be extended to systems of partial differential equations. This general principle, whose explicit formulation seems to be new, then was applied to obtain as special cases well-known solutions of the heat equation, the wave equation, and nonlinear partial differential equations of fluid dynamics.

### ELECTRIC ANALOG COMPUTER

The California Institute of Technology Electric Analog Computer, although only partially completed, was placed in operation in June 1947. Since this time it has been in full-time use as a computing service to West Coast industry and as a research facility for the Institute. This computer which was described by E. L. Harder (M '41) of the Westinghouse Electric Corporation, East Pittsburgh, Pa., and G. D. McCann (M '44) of the California Institute of Technology, Pasadena, Calif., is capable of solving not only linear ordinary algebraic or differential equations and linear partial differential equations, but a wide variety of nonlinear equations. Electric circuit techniques are well suited to the solution of linear problems. The versatility of this computer has been extended greatly by the development of suitable electronic amplifiers, multipliers, and elements for the representation of general functions of both the independent and dependent variables. Since being placed in service it has been used principally by the southern California aircraft industry and the California Institute of Technology jet propulsion laboratory for the solution of such problems as those encountered in the analysis of autopilot and missile control systems, aerodynamic stability, landing shock, and other structural stress problems.

# Arc Welding Problems Discussed at Thursday Session

Three conference papers on various problems in arc welding were presented at a Thursday morning session of the AIEE winter general meeting in Pittsburgh, Pa. The session was presided over by E. S. Steinert (A '27) Westinghouse Electric Corporation, Buffalo, N. Y.

### POWER SUPPLY PROBLEMS

Various aspects of welding power supply problems were discussed in a paper called "Electric Power Supply Problems of Inert Gas Arc Welding," by A. U. Welch (A '36) General Electric Company, Holyoke, Mass. Inert arc welding (fusion of metal by an electric arc between the metal and a refractory electrode in an atmosphere of inert gas) is accomplished generally with alternating current. Direct current causes excessive heating of the electrode, uncontrollable melting, and also mechanical instability of the arc. A-c inert arc welding requires special power equipment and may cause unusual demands on the power supply circuits. The usual a-c arc-welding transformer will not operate successfully an inert arc because the open circuit or restriking voltage required to start current flow for the half cycles when the work is negative, is far above that of the transformer. Two different equipment designs have been developed to permit inert arc welding with moderate power voltage. One method uses the addition of a high-frequency pilot to a welder of usual voltage. The pilot superposes on the 60-cycle power a high voltage at frequent intervals, usually many times in each half cycle of the 60-cycle current. By this means the working negative half cycles can be started each time and the fluxless welding is possible. Frequencies in the order of 100 kc to 2 megacycles are used generally. Unfortunately the high voltage at these frequencies causes considerable radio noise to be radiated from the welding lead. Complete shielding such as placing the entire equipment and work in a metal-clad room and filtering all incoming power lines is usually very expensive. The low-frequency part of the circuit presents additional problems. The tungsten electrode used in inert arc welding operates very much hotter than the molten metal being welded and emits electrons much more readily. This results in a d-c component of current. The direct-voltage component is a function of electrode size and temperature, arc length, and gas used, and is generally in the range of 4 to 12 volts. The d-c component is subject to variation depending upon the equipment used, and is equal to the voltage divided by the d-c resistance of the welding circuit. The rating and design of the welding transformer also will affect this value. Tests on typical equipments show d-c components ranging from 40 to 70 per cent of the total rms secondary current, with 50 per cent as the most usual. The d-c component is so large as to cause serious problems in addition to the nuisance problem of forcing the use of a large direct-reading a-c ammeter to measure current because a current transformer is useless in such a circuit. Other problems involved in inert arc welding include saturation of the core which produces undesirable harmonics. It was pointed out that a type of the inert arc welding equipment has been designed which eliminates all the problems of saturation, harmonics and high input by the use of a low-voltage series capacitor in the welding circuit to suppress the d-c component. Secondary and primary currents are practically pure sine waves as a result. The arc stability is increased greatly by this circuit, and by a moderate increase in secondary voltage (from 75 to 100 volts) it is possible to eliminate the high-frequency pilot with its attendant radio noise problems. Even though the 33 per cent increase of voltage needed for eliminating the high-frequency pilot increases the kilovolt-ampere input, the net input is less than for a 75-volt welder without d-c suppression. Comparison was made between a standard 75-volt 220-ampere arc welder with the usual 5-kva power factor correction capacitor, and a standard 100-volt 400-ampere inert arc welder with 7.5 kva of capacitance, both operating at 145 rms output (38 per cent direct current in the 75-volt welder). The tested inputs were 11.7 kva in the 75-volt welder and 7.6 kva in the inert arc welder, a reduction of 35 per cent.

### FARM WELDERS

"Power Supply for Farm Welders," was a paper by A. H. Matthews (M '46) and G. V. Patterson (A '47), Ohio Power Company, Canton, Ohio. The electric welder, regardless of type, cannot be considered a very desirable load for the electrical utility to serve; however, the benefits that accrue for the farmer are such that it is necessary that electrical utility companies give full consideration to methods of serving the arc welding load on the farm. The introduction of the limited-input welder or farm welder in the latter part of 1945 presented a problem for the electrical utilities. This welder had characteristics which minimized to some extent the disadvantages of the industrial type of arc welder as far as a utility load was concerned. The Ohio Power Company decided to study the effect of the operation of the welder on their system and to formulate a policy under which electrical service could be made available for its use. The study showed that the farm welder could be served from the rural distribution system without any particular trouble provided the customer is served with a 3-kva or larger transformer. The 3-kva transformer is predicated on its being large enough to handle the customer's normal electrical service requirements. The general welding policy as applied to commercial and industrial installation of welders fundamentally takes this position. If there is ample capacity in the present facilities to serve the welder without disturbing service to other customers served from the same facilities, the operation of the welder is permitted in conjunction with the customer's regular service without imposing any special charges. The farm welder policy permits

the use of a welder with characteristics within those specified for the limited-input type arc welder with the further proviso that it shall not draw more than 37.5 amperes from the line at 230 volts. The welder is served in conjunction with the farmer's normal service account without any special charges. It is hoped that the majority of the farm customers who would buy welders already would be served individually from a 3-kva transformer, however, if that is not the case the company will install such transformer without charge to the customer. There are only two restrictions as to the use of a farm welder on the company's lines. One is that it must have characteristics within those specified by National Electrical Manufacturers Association standards for the limited-input type welder, and that it not draw more than 37.5 amperes from the line at 230 volts. The second is that the welder must be used for the repair of customer's own equipment. If the welder is used by the farmer in the operation of a commercial welding shop, the problem then is approached as that of a commercial nature. A survey made in June 1947 indicated that 600 of the Ohio Power Company's farm customers were using farm welders. In serving these 600 farm welders it was found necessary to change only 153 transformers to 3-kva or larger transformers.

Also presented at this session was "Electrical Characteristics of the Arc in Heliac Welding," by H. T. Herbst, Linde Air Products Company.

# Thursday Session Presents Discussion of Extra-High-Voltage Cable Systems

Five technical papers discussing extra-high-voltage cable systems were presented at a session on Thursday, January 29. The chairman at the session was L. F. Hickernell (F '34) Anaconda Wire and Cable Company, Hastings-on-Hudson, N. Y.

### HIGH-VOLTAGE COMPRESSION-TYPE CABLES

The first paper, "A 138,000-Volt Polyethylene-Sheathed Compression Cable—Pipe-Line Type" (48-71), was divided into sections each of which was contributed by one or more of the authors: J. E. McCormack (F '44) and C. T. Hatcher (M '37), of the Consolidated Edison Company of New York, New York, N. Y.; Kenneth S. Wyatt (M '39), W. A. Del Mar (F '20), E. J. Merrell (A '41), and J. H. Palmer (M '42), of the Phelps Dodge Copper Products Corporation, Yonkers, N. Y.; and E. F. DeTurk (M '30), of the Long Island Lighting Company, Mineola, N. Y. Disadvantages of increased load losses and possible rupture when lead sheathing was used led to the development of a polyethylene-sheathed compression-type cable for high-voltage transmission on a tie-line. In presenting this paper, both the history of high-voltage compression-type cables and their basic characteristics were discussed. Comprehensive tests have been made on new cables which indicates the improvements that have been made over previous types. Cable joints, termination equipment, and pressure control equipment were discussed in connection with the new cable. Installation data and procedure were given.

### NEW ORLEANS INSTALLATION

"A 115-Kv High-Pressure Oil-Filled Pipe Cable Installation in New Orleans, La." (48-72), was described by W. R. Bullard (M '26) of Ebasco Service, New York, N. Y.; A. D. Pettee (F '46) of the General Cable Corporation, New York, N. Y.; and G. L. Rhodes (A '36) of New Orleans Public Service, New Orleans, La. This was the first major high-voltage pipe-type installation in the United States to be installed without any stop joints and without the use of the conventional temporary lead sheath. Inherent strength and simplicity were adopted as the keynotes of design to prevent frequent digging up of sections. External sleeves were used at the welded joints. Asbestos felt-coal tar enamel combination was selected for outside protection against pipe corrosion, a rust-inhibiting enamel was used inside, and electrical protection from corrosion was provided. It was deemed unnecessary to use semistop joints for sectionalizing, thereby enabling the omission of all permanent manholes. The cable design, manufacture, and steel construction of this unique installation was described in detail.

### TEST RESULTS

Tests on ten samples of two types of high-voltage cables in connection with a 120-kv 95,000-continuous-kva installation were made several years ago. Results of these tests, which were classified under "Thermal Characteristics of a 120-Kv High-Pressure Gas-Filled Cable Installation" (48-73), were described by W. D. Sanderson (M '41), and Joseph Sticher (M '39), of the Detroit Edison Company, Detroit, Mich., and M. H. McGrath (A '26) of the General Cable Corporation, New York, N. Y. Artificial loading, thermal characteristics, power factor data, and loading periods were provided for. Results of the tests were given in table form. Data indicated that better thermal characteristics are obtained when nitrogen is replaced by 700-second oil as a compression medium, and that position of the cables in the pipe had no effect on thermal resistivity of the insulation or of the surface of the pipe, but that position did alter the thermal resistivity between the cable and the pipe. Increase in thermal resistance with decrease in temperature appears to be in the neighborhood of ten per cent. Conclusions drawn from field tests were given with respect to temperature surveys, soil resistivity, surface resistivity from pipe to air, thermal resistivity of pipe covering, surface resistivity from cable to pipe, other thermal resistances, increase of loss as a result of the steel pipe, and power factor measurements.

### USE OF MODELS

As a continuation and refinement of a paper, published in 1946, Andrew Gemant and Joseph Sticher (M '38) both with The Detroit Edison Company, Detroit, Mich., presented "Use of Reduced-Scale Models for the Solution of Cable Temperature Problems—Part II" (48-7). The method for determination of cable temperatures based on dimensional analysis and scale-reduced models was applied to four field problems and results compared with measured data. The effects of the moisture condition and location of the cable in the duct bank were discussed and equations developed to enable correction for moisture content. The temperature-time curves can be used to determine from the model installation maximum temperatures, relative life of cable insulation, and rate of rise of cable temperature. The adaption of this method to 3-dimensional problems, such as that of a steam pipe running close to a cable duct at an angle with it, was discussed and analyzed.

### LOCATION OF GAS LEAKS

A new method of locating gas leaks in pressure cables by co-ordinated use of pressure gauges, introduction of tracer gas, and observation of the forced and natural movement of the tracer gas was described by John D. Piper, The Detroit Edison Company, in his paper, "Location of Gas Leaks in Pipe-Encased Gas Pressure Cable Lines" (48-3). The effect has been minimized of difficulties such as traveling waves of gas pressure, "entrapped" wave crests at valves, unequal heating and cooling rates along the line, and mixing of tracer gas with the nitrogen. The author gave a detailed analysis of procedure, equipment, and interpretation of data. Although the system has not been in use long enough to determine its accuracy, it seems to be a practical means for locating leaks without the interruption of service.

## Mechanical Rectifiers Discussed at Thursday Conference

A well-attended conference on mechanical rectifiers was held in Pittsburgh on January 29, under the joint sponsorship of the AIEE electronic power converter committee and the electronics committee. The following report on the conference was submitted by H. Winograd (F '46, Allis-Chalmers Manufacturing Company, Milwaukee, Wis.), chairman of the electronic power converter committee, who presided over the meeting.

A mechanical rectifier, used for converting a-c power to d-c power, consists of a set of synchronously-driven contacts which are connected between the rectifier transformer

and the d-c load circuit. The contacts take the place of the rectifying elements of a mercury-arc rectifier, or other types of static rectifiers. Mechanical rectifiers for small currents have been used for many years. However, efforts made in the past to develop such rectifiers for higher currents were unsuccessful, largely as a result of the problem of commutation. Interest in this subject has been revived by the development and commercial application in Germany, during the war, of high-current mechanical rectifiers for ratings up to 5,000 amperes at 400 volts direct current per set of six contacts.

Four conference papers were presented, covering the history of mechanical rectifiers, the commutation problem, commutating reactors, and the German mechanical rectifier.

### HISTORY

In his paper, "History of Mechanical Rectifiers," J. T. Thwaites (M '44) division engineer, electronics division, Canadian Westinghouse Company, Hamilton, Ontario, Canada, outlined the historical background in the development of mechanical rectifiers. He showed slides of various designs used in the past, described their construction, and mentioned some of their shortcomings. He showed one type dating back to 1887.

### THE COMMUTATION PROBLEM

Walther Richter (F '42) consulting electrical engineer, Allis-Chalmers Manufacturing Company, Milwaukee, Wis., explained the commutation process in rectifiers, in his paper "The Problem of Commutation." He pointed out that commutation does not pose any problem in mercury-arc rectifiers, because the circuit of each phase is opened automatically at the point of zero current, at the end of its conducting period, by the valve action of the rectifying elements which prevents reversal of the current. This action, however, does not exist in a mechanical rectifier, and the circuit of each phase would have to be opened by its contact at the instant of zero current at the end of the commutation period, to avoid destructive arcing or reversal of current. Mr. Richter stated that this would be physically impossible, because of the high rate of current change at the end of the commutation period. He concluded that it would be impossible to make a successful mechanical rectifier for high current if an additional element were not introduced into the circuit to provide a period of near-zero current at the end of the commutation period, of sufficient duration to permit opening of the contact. This was accomplished in the German mechanical rectifier by means of special commutating reactors.

### COMMUTATING REACTORS

B. D. Bedford (M '43) of the general engineering and consulting laboratory, General Electric Company, Schenectady, N. Y., explained the function of commutating reactors and discussed their design. The reactors are connected between the rectifier transformer and the mechanical rectifier. The reactor core is saturated by the rectifier current during the conducting period, but becomes desaturated at the end of the commutation period near the point of zero current, thereby introducing a high reactance into the circuit between the commutating phases. The reactor absorbs the voltage difference between the phases for a certain period, during which only the exciting current of the reactor flows through the rectifier contact. This provides the near-zero step of current during which the contact can open. The size of the reactor depends on the magnitude of voltage to be absorbed, the duration of the step, and the permissible exciting current to be interrupted by the contact. (In the German rectifiers the duration of the step was about one millisecond and the current a fraction of an ampere.) The reactor core has to be made of a special alloy steel, having a magnetization curve with a sharp knee, and low magnetizing magnetomotive force below the knee. It was mentioned also that small commutating reactors have been used to advantage with mercury-arc rectifiers, to provide a step of low current near the end of the commutation period, which allows additional time for deionization before the anode becomes negative to the cathode.

### GERMAN RECTIFIERS

Otto Jensen (A '41) manager rectifier division, I-T-E Circuit Breaker Company, Philadelphia, Pa., described the mechanical rectifier developed in Germany. Mr. Jensen, who made two trips to Germany after the war, stated that mechanical rectifiers with an aggregate current capacity of 110,000 amperes direct current were in operation in Germany by the end of the war. He explained, with slides, the construction of the German rectifier, the rectifier circuit, and the operation of the commutating reactors. The contact are operated by rocker arms, which are actuated by eccentrics on a shaft driven by a synchronous motor. The busbars of the contact mechanism are liquid-cooled. Force-feed oil lubrication is provided for the bearings. In the event of a commutation fault, the rectifier contacts are protected by a high-speed switch, which applies a short circuit between the rectifier and the commutating reactors. Curves were shown which compared the efficiencies of mechanical rectifiers, mercury-arc rectifiers, rotary converters, and motor generators. The curve for the mechanical rectifier was higher than for the other converters up to 800 volts direct current, the difference being pronounced particularly at the lower direct voltages. The operating experience with mechanical rectifiers in Germany, according to Mr. Jensen, was varied, and the contact life varied from two days to 18 months, depending on the characteristics of the a-c power system. On stable power systems good operation and reasonable contact life was obtained. Poorer operation and shorter contact life were experienced when the power system was subjected to frequent disturbances or interruptions. Mr. Jensen preceded the presentation of his paper with an entertaining account of his trip to Germany.

### DISCUSSIONS

Discussions followed the presentation of the papers. W. E. Gutzwiller (M '40) Allis-Chalmers Manufacturing Company, took issue with the efficiency curves for rectifiers shown by Mr. Jensen, which were based on European multianode mercury-arc rectifiers. He said that on the basis of American single-anode mercury-arc rectifiers and a more recent efficiency curve for the German mechanical rectifier, the two types have about the same efficiency at 600 volts direct current, and that the difference in favor of the mechanical rectifier at the lower voltages was not as high as shown. He expressed the opinion that mechanical rectifiers might find application for the lower direct voltages, but that operating experience is needed to determine their suitability for American service conditions.

R. C. Bergvall (M '41) and L. A. Kilgore (F '45), Westinghouse Electric Corporation, presented discussions. Mr. Bergvall expressed the opinion that further improvements and substantial development expenditures would be required to make the mechanical rectifier suitable for the operating conditions in the United States. He said there would have to be a sufficient market for this equipment, for applications requiring low direct voltages, to justify the development expenditure.

W. R. Streuli (A '46) of the Brown, Boveri, and Company, Ltd., Baden, Switzerland, showed a slide of an experimental mechanical rectifier built by his company and installed in an aluminum reduction plant in Switzerland in 1944. The rectifier was rated for an output of 8,500 amperes at 400 volts direct current. Hes aid that his company still considers the mercury-arc rectifier the preferred a-c to d-c converter.

## Fault Limiting Devices Discussed at Thursday Session

A technical session on Thursday of the winter general meeting was devoted to a discussion of the subject of fault limiting devices. Chairman at this session was H. R. Stewart (M '39) New England Power Service Company, Boston, Mass.

### GROUNDING PRACTICES

The opening paper originally was presented at the AIEE Midwest general meeting, Chicago, Ill., November 3–7, 1947. "Present-Day Grounding Practices on Power Systems" (47-237), was prepared by the AIEE committee on present-day grounding practices from replies to questionnaries submitted to public and private utilities in the United States and Canada having a generating capacity of more than 10,000 kw, or having more than 10,000 customers. The report covers separately the grounding practices on generating stations and on transmission and distribution systems. Its scope is indicated by the fact that the information on generating stations was drawn from 460 systems operating at 11 kv and

above (involving 33,752 megavolt-amperes in generating capacity in 972 generating units), and the grounding data on transmission and distribution systems were drawn from 567 systems operating at 22 kv and above (involving 119,081 miles of transmission and distribution circuits). These figures denote that information was obtained on about three-fourths of the facilities existing in the classes investigated.

PROTECTIVE EQUIPMENT

Sixty-one privately owned and operated utilities throughout the United States were questioned in compiling a report on "Survey of Lightning Protective Equipment for Rotating A-C Machines" (48-78), which was prepared by the lightning protective devices subcommittee of the AIEE protective devices committee. Both the questionnaire and a careful tabulation of the answers were presented. In general it seems that past experience determined the installation of lightning protection on rotating a-c machines, with exposure conditions rather than size being the determining factor. Arresters and capacitors in combination seem to be in most general use. Several companies have tests in progress to determine the need for and results obtainable from lightning protection of rotating a-c machines.

SPARKOVER CHARACTERISTICS

The next presentation was another report of the AIEE lightning protective devices subcommittee, "Expulsion-Type Lightning Arresters' Impulse Sparkover Volt–Time Characteristics" (48-79). Data from seven manufacturers pertaining to arresters as now manufactured were collected and used to obtain impulse sparkover characteristic curves as advantageous in AIEE proposed Standard 47. Comparison of the impulse sparkover characteristic of an expulsion arrester with the impulse withstand voltage strength of the insulation to be protected will insure a satisfactory margin of protection.

# Technical Session Features Discussion of Facsimile and Picture Transmission

Various aspects of facsimile and picture transmission were discussed at a session which featured five papers, four of which were the conference type of paper. C. L. Callahan (M'35) RCA Laboratories, Radio Corporation of America, New York, N. Y., presided over the session.

TELETAPE

"Western Union Teletape Facsimile" (48-74) was presented by Leon G. Pollard, of the Western Union Telegraph Company, Water Mill, N. Y. The application of Teledeltos paper for both transmitting and receiving has made possible a relatively low-cost means of transmitting written intelligence between two or more points. A 4-point rotating stylus is used for scanning a message written on Teledeltos paper with a soft lead pencil or specially prepared carbon paper. Reception is very similar to other facsimile reproducers. If both transceivers are fed from the same 60-cycle power system, synchronizing and phasing is assured by the initial adjusting of the stylus on each machine so that the tips are in the same relative position with respect to the 1,800-rpm driving motor. Relays operated by the cover of each machine (which must be opened before a message can be written, and closed before a message can be sent) prevent simultaneous transmission of more than one message, insure that the correct transceiver functions as a transmitter and that the others function as receivers, and notify the operator if the receiver is not turned on. The auxiliary power and control units consist of two amplifiers, one for transmitting and one for receiving, and a Wheatstone bridge for signal modulation.

USE OF TELEPHONE CIRCUITS

"Use of Telephone Circuits for Picture and Facsimile Service" was presented by I. E. Lattimer (M'35) American Telephone and Telegraph Company, New York, N. Y. This paper first traced briefly the evolutionary development of long-distance telephone plant, from open wire to coaxial cable and the radio relay system. It then discussed the characteristics of telephone-type channels derived from existing types of plant and the influence of these characteristics on their use for picture and facsimile transmission. Of particular interest in this respect were band width, envelope delay, echo, and effects of automatic transmission regulating systems. Three general methods of attack have been made on the problem of utilizing telephone circuits. These are: first, use of regular long-distance message connections; second, use of full period or short period telephone service; and third, development and use of a completely co-ordinated system of channels and machines. The relative advantages and limitations of these different methods were compared. The general requirements for picture and facsimile transmission were outlined and the features of a completely co-ordinated system were discussed in some detail. Different systems of picture carrier transmission; that is, single and double sideband amplitude modulation, and frequency modulation were compared in applicability. Special transmission considerations are involved when long circuits are connected together to form networks, including arrangements

**Participating in the Thursday session on power distribution in the mining and glass industry are (left to right) Chairman R. T. Woodruff, Aluminum Ore Company; James P. E. Arberry, Pittsburgh Plate Glass Company; Albert Brown, Philadelphia and Reading Coal and Iron Company; D. J. Baker and M. W. Pennybacker, I-T-E Circuit Breaker Company**

**Shown at the general applications to mining session are (left to right) A. C. Muir, Berwind-White Coal Mining Company, presiding; W. R. Morton, General Electric Company; C. O. Wood, Goodman Manufacturing Company; and D. E. Renshaw who is associated with the Westinghouse Electric Corporation**

for bridging and signaling. Special attention must be given to avoiding return current effects and excessive noise. Provisions for supplementary speech transmission usually are required. Special testing techniques are required, both in connection with setting up picture and facsimile networks, and in their maintenance and operation after they have been established. These are concerned particularly with improvement and maintenance of delay characteristics and of detection and prevention of echoes and interference effects. A great deal of thought and effort have been expended in the past by engineers and others outside of the telephone companies in an endeavor to find the most practicable and efficient way to make use of telephone circuits for picture and facsimile transmission. This paper presented a co-ordinated view of the pertinent factors involved, with the thought that future thinking along this line may be helped to correct conclusions as to what may or may not be practicable.

FACSIMILE TRANSMISSION SPEED

H. F. Burkhard, United States Army Signal Corps Laboratories, Red Bank, N. J., presented a paper called "Considerations on Facsimile Transmission Speed." This paper described some of the factors limiting the transmission speed of facsimile copy and some of the approaches to the problem of increasing the speed. These include special scanning methods, improved means for modulation and demodulation, more efficient use of the available frequency channel, and the use of wider channels.

Speed of transmission usually is limited by the usable band width of the available transmission network, but in some instances by the limited recording speed of the recording medium. As the scanning spot is just as likely to scan wide areas of constant shading as to scan isolated narrow lines, the anticipated frequency range of signals generated in the photoelectric tube circuit is from practically direct current to an infinite frequency. In practical design this range is considered to be from direct current to the fundamental frequency generated by the scanning of alternate black and white lines, each equal in width to the scanning aperture. This range makes it necessary to place the modulating or photoelectric tube signal on a carrier. Two methods were described for finding the distribution curve of amplitude versus frequency which results from the scanning of an isolated spot or line. The maximum frequency which must be transmitted to reproduce the isolated spot is about ten per cent greater than the value of maximum frequency which is considered necessary when calculated by the alternate black and white line method of analysis. Industry in general, however, uses the alternate line method of analysis for two reasons, namely: the analysis is simpler, and in most instances where the resulting maximum value of frequency is to be applied, the application is based upon empirical test data from actual operation of the equipment. Attempts are being made to utilize the available channel more efficiently. Delay distortion is usually the critical factor. For no distortion all frequencies must be transmitted through the transmission medium at the same rate of speed. The figure of permissible delay distortion of plus or minus 250 microseconds per 1,000 cycles of modulating frequency was confirmed and the special case where this figure may be extended to plus or minus 500 microseconds was described. By including delay limits in the requirements for new army wire and radio circuits it is hoped that the transmission speeds of future military facsimile equipments will be more than double present speeds. With modulating frequencies approaching four-fifths of the carrier frequencies, special precautions must be taken while modulating or demodulating. Several of these precautions were described, including heterodyning and quarter-phased methods of detection. A balanced photoelectric tube modulating circuit also was shown. The transmission study using wider channels up to 192 kc was outlined. A method was given for using slower speed recording papers at the higher rate of speed.

FACSIMILE TRANSMISSION OF TELEGRAMS

Apparatus designed for facsimile transmission of telegrams was describe in a paper called "Facsimile Transmission for Pickup and Delivery of Telegrams" by G. H. Ridings, Western Union Telegraph Company, Water Mill, N. Y. In practice this device is used as follows: The user types a telegram, inserts it into the machine, presses a button, and the telegram is reproduced in the Western Union office. There, it is transmitted in the normal manner to its destination where the receiving operator puts it into another facsimile machine, presses a button, and the telegram appears on the machine on the desk of the person to whom the message was sent. According to the author it will be possible eventually to substitute facsimile transmission for regular transmission between offices.

"Standards for Facsimile Broadcasting," by J. V. L. Hogan (M '20) Radio Inventions, Inc., New York, N. Y., also was presented at the session.

# Resistance Welding Is Subject of Pittsburgh Meeting Session

C. E. Smith (M '44) The Taylor-Winfield Corporation, Warren, Ohio, presided at a session on resistance welding on January 29. Three conference papers were presented at this Thursday afternoon session.

IN THE STEEL MILL

"Resistance Welding Equipment Used in Steel Mill Strip Processing," was the title of the paper presented by J. J. Riley of The Taylor-Winfield Corporation.

For the past ten years the use of resistance welding equipment for joining strip in steel mill processing lines has advanced steadily until today it is an established production tool. The different types of equipment allow flexibility for consistently making the highest quality weld regardless of welding process, or for making welds with the quality only sufficient to safely insure passage through the processing steps involved after which the welds are cut out. In normal procedure the highest joint efficiency requirements are made by using butt joints using the flash welding process. The less critical joints, those of low efficiency, usually are made as lap joints by using either the seam or spot welding processes.

Resistance spot welding equipment for steel mills may take any form, but it has to be rugged and inherently require a minimum of maintenance and yet provide greater ease of operation than equipment for many other industries. This is paradoxical as the average spot weld made in steel mill applications is of exceptionally low quality. Spot welds can be made by using portable equipment which requires the maximum degree of operator effort and generally results in the slowest working rate for joining the sheet, or the equipment may be developed so that the operator has only to position the spot welding electrode and both the welding force and welding current automatically are controlled. Spot welding type of apparatus generally is used in those processing steps which require welds to be made in times of from three to five minutes across a sheet of approximately 30-inch width.

To cover those conditions where spot-welded joints must be made in less time, the seam welder has been developed. This welder makes a series of spot welds using roller-type electrodes and inherently will produce a joint more quickly and, most of the time, more satisfactorily. Such equipment is designed so that strip width within the capacity of the machine does not vary the welding current resulting from the magnetic characteristics of the strip. A detailed description of such apparatus was included in the paper. In conjunction with the description of the apparatus a welding data chart showing the rates of speed for various thicknesses of strip welded on such apparatus was presented.

When higher quality welds and joint efficiencies must be obtained, the flash welding equipment is a logical selection. These joints are not removed from the strip after they are made but form an inherent part of it and are used in industry as part of the strip and, consequently, must have physical characteristics equivalent to the strip. There are two general types of flash welders used in making

flash-welded joints in steel mill strip. The first type commonly is classified as "motor drive or mechanical" and the second type as hydraulic. A preference for and a general description of the hydraulic types were included by Mr. Riley. The flexibility of operation of the hydraulic type of equipment in addition to the possibility of varying the various times of the flashing cycle independently of each other, points to its use on the more critical application. The addition of a dual voltage system bearing a flashing operation greatly has minimized weld breakage because of uncontrolled shearing which ordinarily results from uneven heat input along the line of weld.

A flash weld in a steel mill application generally is trimmed by a trimmer whose function it is to remove the flash. The requirements of a trimmer and an illustration of one were included in the paper, which concluded with a table showing the hardness differential of a flash-welded joint and a photomicrograph of the various structions in and surrounding a flash-welded joint. In addition, a third table pointed to the degree of quality possible in flash-welded joints using tensile strength as a criterion.

### SUBCOMMITTEE PROGRAM

A "Summary of Work and Program of the Subcommittee on Power Supply for Resistance Welding Machines," was presented at the resistance welding session. This subcommittee is under the chairmanship of C. M. Rhoades, Jr. (A '41) General Electric Company, Schenectady, N. Y. In the fall of 1947 the electric welding committee established a subcommittee to review the general question of power supply for resistance welding machines and prepare a report which would supplement and bring up-to-date the very valuable paper on this same subject prepared by a similar subcommittee in 1940 and 1941. While it is too early to report the progress of the present committee, it is important that the scope of the work and the problems involved be made known to all those interested in this subject so that further suggestions and technical data required will be forthcoming from engineers interested in this subject. The previous report was issued in two papers, the first covering a guide to good electrical performance of welding machines (40–57) and a summary of resistance welder installations (40–58), while the second paper (41–82) which was issued about a year later outlined considerable technical data and methods for selecting factory distribution systems for power supply to welders. Since these papers were presented, there has been increased interest on the part of utilities in this question of power supply for welding machines, new methods for reducing the kilovolt-amperes drawn by welders have been introduced, and more modern practices in the layout of general factory power distribution systems have been evolved which influence selection of similar equipment for welder power supply. It is, therefore, quite appropriate that this subject be reviewed.

The members of the new subcommittee, in view of the broadened scope of the work of the committee, include representatives of utilities, welder manufacturers, users, and electric equipment manufacturers. The American Welding Society and the Canadian Electric Association also are represented. The Canadian Electric Association is undertaking a similar program; hence, the need for co-ordination between the committees. The committee members will act as representatives of the engineering groups with which they are associated and will welcome suggestions and aid from all those interested in helping with the program. The program is a very large one and it is expected that the committee will confine itself largely to correlation of existing information as well as initiating work by others directed toward filling in those areas where information is not already available. As in the case of all committee activities, a good share of the work must be done by the committee members themselves, but the committee wishes to emphasize the fact that considerable outside help will be required if the program is to be completed within the year or so allotted. Additional appointments will be made to the committee whenever necessary. The program which has been approved by the committee can be broken down into three parts:

1. To provide basic information relating to the power requirements of resistance welding machines and the effect of resistance welding loads resulting from single machines and combinations of machines. The standpoint of both the user and utilities will be taken into account.

2. To outline the basic economic considerations in provision, purchase, and utilization of power for welding. This will include consideration of power factor correction and the relationship between welder load and general plant load as they may affect selection of power supply equipment.

3. To set up desirable practices and methods of procedure to be used in the selection of adequate power facilities for resistance welding.

A good share of the information contained in the earlier report is applicable to the present report. However, a large number of installations of power distribution equipment within new factories have been made during the war years and a summary of the outstanding installations will be quite helpful. The committee expressed the hope that all engineers will see the advantages of its work and will contribute whatever they can so that the goal can be reached promptly.

The first paper aptly was entitled "Resistance Welding" and was presented by J. F. Deffenbaugh (A '42) and F. A. Bodenheim, Jr., of the Federal Machine and Welder Company, Warren, Ohio. Although universally acknowledged as the best tool for sheet metal fabrication, the full potentialities of resistance welding often are not recognized. After a brief review of the theory and control practices, the authors used slides to describe the four main types of resistance welding. Spot welding is used for fabrication of metal parts requiring many spaced welds or welding on various planes. The conventional standard single spot welder uses a rocker arm for carrying the movable electrode. Another standard spot welder, the press type, uses direct vertical action controlled by precision slide ways. Special designs, such as the portable gun welder and the multiple spot welder, are used widely for specific or single-purpose applications. Projection welding reduces production costs by enabling many welds to be made at one machine cycle. It also is suited to applications where surface marking on the show surface on one of the parts is a critical factor and whenever design requirements necessitate several welds in a relatively small area. The more common types of projection welds are the button or dome-type and cross wire welding. The press-type machine usually is used for projection welding. Seam welding provides pressure-tight joints or a long row of spots on a flat piece or acts as substitute for deep drawing operations. Butt and flash-butt welding employ a different procedure for obtaining the necessary heat for welding and are particularly applicable to end-to-end welding.

# Electric Network and Circuit Theory Reviewed at Meeting Symposium

The symposium on network and circuit theory which was held January 29 under the auspices of the network subcommittee of the basic science committee attracted an attendance of approximately 175. Although recent advances have been made in electric network theory, little has been published because of wartime security restrictions. Therefore a symposium devoted to a review of the developments of the last decade and a discussion of new problems in the field of linear network theory was quite appropriate. J. G. Brainerd (F '47) of the University of Pennsylvania, was the presiding officer.

R. L. Dietzold, of the Bell Telephone Laboratories, New York, N. Y. presented and discussed general network theory in the light of unpublished wartime studies.

### NETWORK SYNTHESIS AIDS SERVOMECHANISM DESIGN

The second paper of the session was presented by E. A. Guillemin (A '24) of the Massachusetts Institute of Technology, Cambridge, Mass. Synthesis procedures for linear passive finite networks now are developed to the point where they usefully can be applied to numerous design problems. While a large variety of practical problems in circuit theory have been solved in this manner, it appears that little use of synthesis has been made so far in the design of control networks for servomechanisms.

The essence of synthesis lies in choosing at the outset a satisfactory over-all response characteristic consistent with the conditions for physical realizability of the linear passive network involved and then proceeding

in a systematic manner with its design without further compromise or trial. The synthesis problem in servomechanism design differs from most usual ones primarily in that part of the system already given, namely the servo motor and its associated mechanical or hydraulic accessories, and this fact injects into the problem certain additional restrictions. This feature, however, is not unique to the servosynthesis problem. For example, in the synthesis of coupling networks for optimizing the power transfer from a source to a given load impedance, the characteristics of the latter inject restrictions whose consideration complicates the synthesis of the coupling network to a degree that makes the servosynthesis problem appear far less formidable by comparison, and yet one has found ways of solving such problems without resorting to cut-and-try methods. If comparable skills are brought to bear upon the servodesign problem, one may expect that here too the cut-and-try procedures gradually will be displaced by methods embodying the true essence of synthesis with its advantage of revealing the optimum obtainable from a given situation. As a modest beginning, the author suggested a way in which a reasonably satisfactory over-all response function may be chosen so as to guarantee the realizability of the transfer function of the control network consistent with the usual characteristics of the fixed elements of the servomechanism. Known methods of synthesis then may be applied to the determination of the control network which is assumed to contain vacuum tubes for providing any necessary gain. Recognizing that in most instances one prefers to restrict the control network to *RC* elements, a summary was given of a paper showing how, except for a constant loss, one can design an unbalanced *RC* network whose transfer function may be made to approximate arbitrarily closely to any given realizable characteristic.

### NETWORK THEORY IN THE POWER FIELD

Symmetrical components were the chief topic of discussion in the paper presented by E. L. Harder (M '41) and C. F. Wagner (F '40) of the Westinghouse Electric Corporation, East Pittsburgh, Pa. Typical charts and curves which simplify calculations were given to illustrate the development and applications of symmetrical components. Thevenin's theorem, Kron's shorthand notation, a-c calculating boards, and analogue computers were discussed as aids in analysis of linear and nonlinear circuits.

### ELECTRIC CIRCUIT MODELS

The symposium was concluded with a discussion of electric circuit models of partial differential equations by Gabriel Kron (M '45) of the General Electric Company, Schenectady, N. Y. Until the last few years the only partial differential equation for which an electric circuit model had been developed was the Laplace-Poisson equation representing a scalar-potential field. The circuit consists of a set of equal or unequal resistances arranged in squares or cubes, often with capacitors leading from each junction to ground and with currents impressed at the junctions. An extension of the network to vector-potential fields introduces a set of inductors and ideal transformers arranged in circles or spheres at each corner of the scalar-potential network to represent the circulation (curl). In the further extension of the model to represent the electromagnetic field the resistances are replaced by capacitors and not only the currents and voltages in the model act as analogues of field quantities, but also the magnetic and dielectric fluxes, the charges, and so forth. In two dimensions a dual form of the network for a *TM* or *TE* model assumes the form of a 2-dimensional transmission line.

A different type of model is the one representing the wave-equation of Schrödinger that describes the waves associated with atomic and nuclear particles. The network gives for any potential energy function the eigenvalues and eigenfunctions of the system, also the statistical mean of the various energy operators.

A still different type of model represents the basic equations of the theory of elasticity. The elastic body may have an arbitrary shape, may be nonhomogeneous, and may rotate at a uniform angular velocity. The networks may show the instantaneous propagation of elastic waves, or may determine their natural frequencies of vibration, or simply may give the strain distributions under static stresses.

All networks are valid in any orthogonal curvilinear co-ordinate system. They may be solved by an analyzer, or by numerical methods. Easily visualizable routine schedules are available (the method of "weighted averages") to solve the network by digital calculating machines. The networks also allow a quick check on the correctness of the results arrived at by other methods of calculation.

# Developments in Magnetic Recording Are Reported at Technical Session

Magnetic recording was the subject of a technical session held on Thursday afternoon, January 29, in Pittsburgh, Pa. Chairman at the session was J. L. Callahan, Radio Corporation of America, New York, N. Y.

### RECORDING TAPES

The opening paper was a discussion of "Magnetic Recording Tapes" (48-75), presented by Marvin Camras (A '41) of the Armour Research Foundation, Chicago, Ill. Magnetic properties, frequency response, signal-to-noise ratio, output level, sensitivity, and erasability of a number of different tapes were compared by showing tabulated and plotted data. Solid metal tape was reported to be best for durability and repeated use. Coated paper or plastic tape is not as permanent, but is lighter, easier to handle, and less expensive. A newly developed coating material which has a balance of the advantageous properties was discussed.

### THE ERASE HEAD

High quality magnetic recording machines which require more complete erasures to reduce the remanent noise below the level of background noise have fostered the development of "A Turn-In-Gap Erase Head for Magnetic Recorders Providing Intense High-Frequency Fields" (48-76), which was described by D. E. Wiegand (A '42) and R. E. Zenner, of the Armour Research Foundation, Chicago, Ill. By placing the excitation of the head just as close to the recording medium as is possible, complete obliteration of the effect of previously recorded signals may be attained at reasonable power input. This head is excited by a single conductor in the erasing gap. The gap conductor is energized by a single-turn secondary winding of a transformer. Greater efficiency in eliminating leakage fluxes and improved thermal characteristics increase the power handling ability of this head. A new playback head providing much higher signals to amplifier input ratio was used in the measurement of remanent signals. Performance data curves of the erase head were given.

### HIGH-FREQUENCY BIAS

"The Practical Application of Supersonic Bias in MagneticRecording" (48-77), was discussed by H. A. Howell, of the Indiana Steel Products Company, Valparaiso, Ind. After an introductory explanation of the theory of magnetization as applied to tape recording, the author discussed the use of a high-frequency biasing field to obtain a linear record. By this method, the remanent induction in the recording medium varies faithfully with the superimposed audio frequency. The cut-and-try method has been used to determine the ratio of bias and audio current and seems to indicate that audio current never should exceed about 25 per cent of the bias. Overload distortion is usually present when the sum of the bias and audio currents is appreciably greater than that of the bias current alone. The coercive force of the recording medium is the prime determinant of the correct value of bias flux. Pre-equalization of the amplitude of the two currents appears necessary to secure a rising frequency characteristic in the recording amplifier. Recording heads and magnetic materials for coated media were discussed briefly.

### RECORDER DRIVE

"Drive Mechanism for High-Fidelity Magnetic-Tape Recorders," was discussed by R. H. Ranger (M '22) and R. H. Kuhnapfel, both with Rangertone, Inc., Newark, N. J. In magnetic tape recording

## Radiant Heating Subcommittee Meets

**Members of the subcommittee on radiant heating of the AIEE electric heating committee who were present at a highly successful all-day meeting of the committee in Cleveland, Ohio, on February 17, were (top row, left to right) Earl Benson, C. T. Prendergast, William H. Wagner, Ernest Upton, Willis F. Hickes, Earl J. Bates (A '43), George A. Medinger, and (front row, left to right) E. A. Lindsay (A '43), J. E. Johanson, Chairman P. H. Goodell (M '46), Secretary Charles E. Russell, Paul O. Blackmore, and James Ernest Sump. The General Electric Company, Cleveland, was host for the morning session and lunch. In the afternoon the group inspected the White Motor Company**

it is necessary that the tape speed be regulated very exactly. A synchronous motor provides the constant tape drive with a pulley directly on the synchronous motor shaft engaging a rubber idler and between the two the tape passes. But the winding of the tape from a release reel to a windup reel can affect this speed. With the changing diameters of the rolls of tape on the reels, the torque moment will vary and this must be compensated by a corresponding variation in the torque of the motor shafts. On the takeup motor, a torque characteristic decreasing practically proportional to revolutions per minute is necessary, and to accomplish this with normal-type motors in view of the low speeds involved, a rubber V-belt drive with pulleys is employed. In addition, the resistance of the motor rotor is increased to weaken the motor torque as its speed increases. As a drag on the release reel spindle, again a V-belt drive is employed to give a step-down ratio, and the best approach to the same decrease in torque with speed is accomplished by applying direct current to the normal field winding. General considerations for the type of spool best suited for handling the tape and the reduction of hum pickup also were considered.

The first conference paper of the session, "Distortions in Magnetic Tape Recording due to the Configuration of the Bias Field," was presented by S. J. Begun, of the Brush Development Company, Cleveland, Ohio. An analysis was given of the effect of the configuration of the magnetizing field in the neighborhood of the gap of ring-type recording heads on the signal as recorded on tape. The author challenged the theory that a "penetration effect" results from a variation of recording depth with wave length by stating other phenomena contribute to the apparent effect of penetration. Distortion does not vary substantially with tape thickness, indicating that the biasing field penetrates as deeply as the signal. However, there is a decided variation of output level with distance from the recording head which is dependent upon frequency. Tests for optimum biasing current show that an increase of 20 to 30 per cent above that which gives maximum response will give minimum distortion. Further increase of biasing current results in high-frequency suppression. The author concluded by encouraging additional detail work to determine the factors affecting distortion.

### General Applications Discussed at Mining Session

General applications to mining was the topic of a session on Friday, January 30, of the AIEE winter general meeting in Pittsburgh. A. C. Muir (M '39) Berwind-White Coal Mining Company, Philadelphia, Pa., presided.

The motors and controls used on underground mining machinery differ from those generally used in industry, principally because of the special conditions existing underground. This fact was brought out in a paper, "Motors and Controls for Underground Mining Machines," by D. E. Renshaw (F '45) Westinghouse Electric Corporation, East Pittsburgh, Pa. It was the purpose of this paper to discuss these special conditions and the features of design and construction which have been or should be adopted to compensate for the difficulties which man and nature have created.

Courtesy Dravo

**An AIEE group watches shearing operations in the structural shop on an inspection trip to the Dravo Shipyard**

This discussion might be summarized as follows. Natural conditions make difficult the design and construction of underground machines. These natural conditions cannot be improved. In fact, they cannot be prevented from becoming worse as the higher coal is mined out. Present and probable future mining practices require that machines be driven at maximum capacity, even though this involves abuse and rapid deterioration of machines. However, even though machine failures may occur too frequently, American production per man a day is still the highest in the world. The benefits of good voltage (or the evils of poor voltage) are known and improvements are being made. This is shown by the installation in coal mines of approximately 400 Ignitron rectifiers since the Ignitron became available ten years ago. Mine maintenance conditions leave something to be desired. More electricians, better stocks of spare parts, and even complete spare machines, would improve conditions. Hazardous conditions are recognized, equipment suitable for hazardous locations is available and is being installed as rapidly as it can be manufactured. Manufacturers realize that they have not achieved perfection. Better equipment of greater capacity is required. Improvements are being made and will continue to be made to meet the continuing demands for safety and reliability in mining machinery.

### PROBLEMS

"Coal mining has problems all its own," said C. O. Wood (M '46) Goodman Manufacturing Company, Chicago, Ill., in his presentation of "Electrical Control Problems in Coal Mines" (48-80). The greatest problem is space limitation and the complication that it brings by outlawing certain solutions to other problems. Supply voltage necessarily fluctuates over a wide range, but in the average mine centers around 250 volts direct current. Motors and control equipment therefore must be designed to withstand overvoltage, to operate satisfactorily on undervoltage, and to continue a given sequence of operation on varying voltage. Specially designed cam-actuated controllers seem to give the best operation. Atmospheric conditions in mines make advisable the use of "permissible" equipment (in which all electric units must be encased in explosionproof compartments and the complete assembly approved by the United States Bureau of Mines). Nitric acid, sulphuric acid, metal dust, and coal dust make corrosion and surface voltage creepage serious problems. Wiring is governed primarily by the permissible temperature rise of each piece of equipment. Maintenance, of necessity, is hurried and of limited scope. Hence equipment must be built rugged, compact, and as simple as possible.

### CONVERSION EQUIPMENT

Because electric power usually comes to the mine as high-voltage alternating current it becomes necessary to convert the a-c supply to direct voltage for the haulage system and for the face equipment. The conversion may be accomplished by several means. Three of these methods and their relative merits were covered in a paper called "Conversion Equipment for Mine Power" by W. R. Morton, General Electric Company, Schenectady, N. Y. Synchronous converters, motor generator sets, and power rectifiers were the conversion methods discussed. The relative merits of each were summarized as follows:

**Power Rectifier**

(*a*). Lowest light load and partial load losses.

(*b*). Relatively high power factor (lagging). Does not supply corrective kilovolt-amperes unless supplemented by capacitors.

(*c*). Less maintenance required than other two types

(*d*). Portable units can be made lower height than other types of conversion apparatus.

(*e*). Easier to install—no heavy foundations necessary.

**Synchronous Converter**

(*a*). Low partial load losses.

(*b*). High power factor (lagging). Does not supply corrective kilovolt-amperes unless supplemented by capacitors.

**Motor Generator Set**

(*a*). Higher losses than other types.

(*b*). Supplies leading kilovolt-amperes for correcting system power factor.

It was pointed out that a comparison of the three types of conversion equipment indicates that each has its place in supplying d-c power in the mine. However, from an over-all viewpoint it appears that the power rectifier readily can meet most mining requirements.

# Low-Voltage Electrical Hazards Provide Theme for Safety Conference

Robin Beach (F '35) consulting engineer, Robin Beach, Inc., Brooklyn, N. Y., presided at a conference on safety on Thursday, January 29, of the winter general meeting. The conference consisted of a 3-part program, the first portion of which was a symposium at which four conference papers were presented: "Why Are Low-Voltage Shocks Hazardous?" W. B. Kouwenhoven (F '34) Johns Hopkins University, Baltimore, Md.; "Why the Electric System in the Home Is Fundamentally a Safe One" and "Where May Low-Voltage Shocks Exist and How They May Be Controlled," W. R. Smith (F '30) Public Service Electric and Gas Company, Newark, N. J.; "Contributions to Safety of National Electrical Code and Inspection Agencies," A. H. Schirmer (M '29) Bell Telephone Laboratories, New York, N. Y.; and "Considerations of Importance in the Design or Selection of Safe Electrically-Operated Portable Tools or Other Portable Electric Equipment," M. M. Brandon (F '44) Underwriters Laboratories, Inc., New York, N. Y.

The second part of the program for the conference was the presentation of a technicolor motion picture film, "The Shocking Truth," through the courtesy of the Liberty Mutual Insurance Company. The conference closed with a general discussion on ways and means of disseminating to the public information on how to guard against electrical hazards in the home from low-voltage circuits and the complements of portable appliances.

The meeting was well attended and the discussion, following the presentation of papers and the movie, clearly demonstrated a very vital and enthusiastic interest in this subject of electrical safety in the home.

### FATAL ELECTRIC SHOCKS

During the presentations, it was stated that about 700 people are killed annually by accidental contacts with low-voltage circuits, mostly in the home and in the use of electrically-operated portable tools and equipment. Such electric shocks resulting from very small currents cause death largely through a peculiarity of the ventricles of the heart to fibriliate whereby they merely quiver rather than continue their normal rhythmic pumping action. Death ensues essentially through the stagnation of the blood system. Thus far in various studies on pressure resuscitation, no success has been attained in reviving victims where this condition of ventricular fibrillation has occurred. Experiments with electric countershock have been applied to animals with some success and studies are going forward in pursuing further this countershock technique.

Ventricular fibrillation is the fatal condition which results especially from a-c low-voltage shocks. The current which induces this condition is of the general order of 100 milliamperes when the current flows through the trunk of the body. Considerably larger values of current during electric shock contract the heart muscles and thereby stop the heart from beating. But in these instances, after the electric circuit is broken, the heart generally resumes its rhythmic action and the circulation of blood is re-established.

The magnitude of current that passes through the body when in contact with a live circuit depends upon many factors: the type of circuit, whether direct or alternating, and the frequency; the voltage; the duration of contact; path of current through the body; and, resistance at skin-area contacts and through the body.

Fundamentally the electric system in the home, as it is installed in compliance with the approved practices of present-day usage, is safe. However, the addition of a wide variety of portable and semiportable electric appliances with their multiplicity of connecting wires introduces hazards of varying degrees which become the offending causes for possible electric shock and injuries. These arise principally from ill-advised uses of multiple outlet receptacles and the promiscuous running of additional wires and electric cords throughout the various rooms of the house and particularly in basements.

The proximity to the electric appliances and their cords of grounded water and gas pipes, radiators, bath tubs, sinks, and other such grounded parts accentuates the ease with which accidental contacts from electric live parts to these grounded systems may occur. Constant vigilance and care in guarding against these hazards throughout the home are necessary in the interest of safe operation. Broken switches, frayed extension cords, uninsulated pull chains, metallically fused circuits, improperly wired lamp sockets and electric connections, and many other abuses to which electric appliances are subjected, all constitute, in the presence of nearby grounded systems, the instrumentalities by which practically all low-voltage electric shocks occur.

### REGULATION FOR SAFETY

To promote safe practices in the installation of electric service and in the use of electric power, various governing agencies have formulated reasonable codes of regulations to guide those who are responsible for the manufacture and installation of all types of electric facilities, appliances, and equipment. The basis of these codes is the National Electrical Code. In many instances municipalities impose local regulatory codes which also must be satisfied.

The workmanship of installing electric circuits and equipment in accordance with the code specifications is subject to inspection and approval before electric service may be connected by the local electric power utility. The inspectors provide more than mere policing service in maintaining the imposed standards of the codes, as contractors frequently call on them for guidance and help in trying to meet safely unusual conditions which require new or more liberalized interpretations of parts of existing codes. It is because of the existance of the various electric codes of standard practices and of the inspection agencies which guard the public welfare within the structure of these codes that the electric system in the home, at the time of its inspection and approval, is a safe one.

The Court of Appeals behind the various codes of electrical installation and practice is the Underwriters' Laboratories whose organized responsibility it is to examine and test all of the innumerable components which constitute the electric system, including not only the types and sizes of wires and the adequacy of their insulation and the many kinds of equipment and fittings used with the wires, but, also, the great and increasing numbers of electric devices, tools, and appliances which operate from the electric circuits. Minimum requirements of safety are established through tests and the accumulation of experience whereby the Underwriters' Laboratories feel justified in giving their stamp of approval and in issuing periodic lists of approved electric parts, fittings, devices, and appliances. The watchword of this organization is "Safety"—safety from fire hazards and safety from electric shock hazards. The work of this organization is of utmost importance in guarding the public against the use of improperly constructed electric components for use in the integrated electric system of the home.

### "THE SHOCKING TRUTH"

The motion picture on "The Shocking Truth" is a dramatic citation in color photography which illustrates in a simple but dynamic manner the various types of low-voltage electric hazards which develop in the home through careless usage and ill-advised practices as so commonly are encountered. This motion picture is still in its developmental stage but it soon will be available through the use of several contemplated reprints for a wide circulation throughout the United States for showings at meetings. The safety committee expressed the hope that this motion picture will be employed as an educational agency in spreading the Gospel of safety, especially safety in the home, from the hazards of low-voltage appliances and circuits.

During the discussion at the safety conference, it was the general concurrence of opinion that a condensed pamphlet be prepared by the safety committee, as was suggested by the chairman, and sponsored by the AIEE. This proposed pamphlet would provide authoritative information on the various forms of low-voltage electric hazards which commonly occur in the home and it would suggest ways and means of recognizing these hazards and of correcting and eliminating their sources. It further was expressed that the AIEE is the organization which should assume leadership in sponsoring a pamphlet on the subject—thus dignifying the pamphlet as a recognized source of authoritative information and giving it the prestige and backing of an outstanding electrical engineering organization.

The pamphlet should be made available, at a small charge, for distribution and use at meetings of civic, church, and women's organizations, and especially at classes in public schools and colleges. It would serve admirably for distribution at meetings where the film, "The Shocking Truth," is shown, and at any other meetings which are devoted to considerations of safety from low-voltage electric hazards.

## Arc Furnaces Discussed at Electrothermal Processes Session

Five papers covering the various phases of control and operation of arc furnaces were presented at a Friday morning session on electrothermal processes during the AIEE winter general meeting in Pittsburgh, Pa. These papers covered the operating requirements as well as design considerations and control apparatus for effective operation. The session was presided over by F. R. Benedict (A '40) Westinghouse Electric Corporation, East Pittsburgh, Pa.

### ELECTRODE CONTROL

The first paper on the program was "Electrode Control and Associated Operating Mechanisms," by E. A. Hanff (A '16) Swindell-Dressler Corporation, Pittsburgh, Pa. This paper did not attempt to cover the technical details of electrode regulators. In reviewing the interesting history of regulator development, comparison was made with the early application of automatic regulation of electrodes in arc lamps where the small currents and light weights permit good control by means of a simple solenoid mechanism. For furnace electrodes, an intermediate power-driven unit is required, necessitating the use of relays and contactors. The improvements made from time to time in regulators have tended to reduce the time lag inherent in power-driven relay-actuated devices. The latest types of rotary regulators provide smoother operation and greatly reduce this time lag as they do not require relays and they move the electrodes steadily rather than in a series of impulses. The relatively higher costs of the rotary types do not appear important when considered as a percentage of total costs, especially on the larger furnaces. The application of limit switches to prevent overtravel of electrodes or fouling of slack hoist cables is discussed. An important improvement now in use to prevent damage resulting from broken hoist cables is described. With this device, a break in the cable brings a simple clutch mechanism into operation, arresting the downward movement of the electrode and gib within a fraction of an inch.

### ROTOTROL CONTROL

A paper describing the application of the Rototrol to electrode control was "Electrode Control for Arc Furnaces," by E. H. Browning (A '43) and C. E. Valentine (M '41), Westinghouse Electric Corporation, East Pittsburgh, Pa. Interest in this subject arises from the demand of the steel industry for closer control of product, greater tonnage output, and lower cost per ton. Particularly in the making of high grade alloy steel, the control and regulation of conditions in the furnace is of prime importance. This paper discussed improvements and developments in regulating equipment for controlling and adjusting the position of the electrodes in the furnace. There are a number of different types of furnaces used for steel making and electrometallurgical processes. These include both open arc, submerged arc, and one, two, or three movable electrodes. The steel making, direct open-arc furnace imposes perhaps the most exacting and critical demands on the electrode positioning regulator. This is especially true during the melt-down period when the charge is undergoing changes in position and form. Current in the electrode may change quickly from small values to short circuit. The regulator must operate quickly and effectively in spite of violent changes to maintain the arcs and control the power in-

put into the furnace. The early regulators responded to current only in the electrodes. In 1920 a balanced beam arc furnace regulator was introduced which had regulating intelligence derived from both the arc current and the arc voltage. The regulating elements controlled reversing contactors which, in turn, impressed direct voltage of one polarity, or of the opposite polarity on the armature circuit of the electrode motor to raise or lower the electrode in the furnace. Most regulators in use today are of this type. Improvements have been made from time to time, thus making the present form of this regulator more reliable, requiring less maintenance, and providing longer life than previous designs. In the early 1940's the rotating amplifier-type regulator was developed, using the same basic current and voltage regulating intelligence. In this regulator, however, static circuits, having no moving parts, are used to control the rotating amplifier, called a Rototrol. The Rototrol provides an output voltage for the electrode motor which varies in magnitude and polarity, in contrast to the fixed voltage controlled by the reversing contactors of the balanced beam regulator. Experience with the Rototrol equipment indicates smoother operation, less electrode breakage, and lower mechanical maintenance than with the balanced beam type. The most effective use, however, of any furnace regulating equipment depends not only on the regulator, but on careful charging, for example, of the furnace and an understanding of the performance of the furnace as regards power input, power factor, arc current, and the tap voltage used. A clear understanding of these relationships permits the operator to select the proper electric circuit conditions, throughout the progress of the heat. With such understanding and care he can use modern regulating equipment best to secure maximum production.

EQUIPMENT AND OPERATION

"Electric Equipment and Operation of Graphitizing Furnaces," was discussed by E. R. Cole (A '24), Dow Chemical Company, Midland, Mich. The arrangements of the relation of the baking transformers—the graphitizing transformer and the furnaces—is different from regular practice. It is customary first to bake the "green" electrodes to the "raw" state up to 1,300 degrees centigrade, in a fuel-fired ring kiln. They then are cooled to room temperature, unloaded, cleaned, and reloaded into the graphitizing furnace. There they again are raised to 1,300 degrees centigrade before being raised to graphitizing temperature of 2,600 degrees centigrade. They are heated to 1,300 degrees centigrade twice. By electrically heating to 1,300 degrees centigrade and then changing to the graphitizing transformer the heating is carried to 2,600 degrees centigrade without interruption. This saves about half the time from "green" electrode to graphite, and all the fuel to heat to 1,300 degrees centigrade the second time and the labor handling out of the kiln and loading into the graphitizing furnace. The kilns and buildings to house them are eliminated. By making the graphitizing transformer portable, the distance to the furnace head is held to a minimum thus reducing the length of the 40,000-ampere conductor circuit to the shortest length possible. This helps to reduce inductive effect. Also, each furnace has a duplicate condition regardless of its location in furnace room. As the transformer is portable, the return side bars along side of furnace, are also portable and this arrangement permits spreading of the bars to envelope the furnace core. When the transformer is stationary it is necessary to have a bus system of 40,000-ampere carrying capacity extend from the transformer to the furnaces, together with selector switches at each station. By having transformers movable, the bus and switches are eliminated.

Also presented at this session were "Experience in Design and Control of Ferro-Alloy Furnaces," by F. V. Andreas, Southern Ferro Alloys Company; and "Electrode Control for Arc Furnaces," by A. R. Oltrogge, General Electric Company, Schenectady, N. Y.

# Session Features Eight Papers on Excitation and Speed Governing

Excitation and speed governing was the subject of a technical session on Friday, the final day of the winter general meeting, which was presided over by A. H. Frampton (F '45) Hydro-Electric Power Commission of Ontario, Toronto, Ontario, Canada. The program consisted of the presentation of eight technical papers on the subject.

GENERATOR STABILITY

"Generator Stability at Low Excitation" (48-2), by E. L. Michelson (M '44) and L. F. Lischer (A '38), both of Commonwealth Edison Company, Chicago, Ill., discussed the stability problems arising from the use of static capacitors for power factor correction. An analysis of typical pull-out curves revealed that constant-terminal-voltage constant-field-current generators can operate in the leading power factor zone and still have ample margin to pick up even abnormal incremental loads. Within the range considered in the study, initial power factor of the machines has very little effect on the transient stability of the system. In general, unswitched capacitors may be added to a 4-kv distribution system until a generator power factor of 1.0 has been reached.

TURBOGENERATOR OPERATION

"Underexcited Operation of Turbogenerators," (48-81), by C. G. Adams (A '41) and J. B. McClure (A '29), both of the General Electric Company, Schenectady, N. Y., stated that turbogenerators are being operated at increasingly higher power factors, sometimes extending into the leading region, because of location of stations and corrective measures applied on the subtransmission and distribution areas of the system. Underexcited operation was re-examined, particularly from the standpoint of system stability and the application of lower excitation limits on voltage regulators. Mathematical analysis which yields acceptable results in spite of simplifying assumptions was explained. A method for readily estimating the stability limit for other machines and system characteristics was included.

ROTOTROLS

"Rototrol Excitation Systems" (48-82), were described by J. E. Barkle (A '40) and C. E. Valentine (M '41), of the Westinghouse Electric Corporation, East Pittsburgh, Pa. The development of the Rototrol amplifier as a portion of the a-c machine excitation system has brought about radical changes in voltage regulators, auxiliary devices, d-c exciters, and manual control devices. The Rototrol exciters are similar in design and appearance to a conventional d-c machine and can be installed on the shaft of turbogenerator systems. The Rototrol pilot exciter is a variable-voltage pilot exciter used to supply the main-exciter field with regulated variable voltage. The Rototrol buck-boost pilot exciter with multiple-field main exciter combination gives more stable operation. With two stages of amplification, Rototrol exciters can be built with outputs capable of supplying the main generator field. The Rototrol excitation system may be regulated by either static-network impedance-type or electronic-type voltage regulators. Special design characteristics may be obtained for particular applications. If used in hydro-electric installations, the Rototrol exciter must be driven by an electric motor. Separate driving motors also are required for application of Rototrol excitation to synchronous condensers.

"Main Exciter Rototrol Excitation for Turbine Generators" (48-83), was a paper by C. Lynn (M '43) and C. E. Valentine (M '41), of the Westinghouse Electric Corporation, East Pittsburgh, Pa. As the size of turbogenerator units increases, continuity of operation becomes a time factor. By eliminating contactors and moving parts, and enabling replacement of impermanent parts during operation by the use of Rototrol exciters, much routine shutdown time can be avoided. Construction and design details of the Rototrol exciter were given and its differences from standard d-c machines were explained. Test data and results were shown. The fact that Rototrol is a series tuned device enables it to utilize the inherent transient characteristic of the a-c

generator field to anticipate regulator action.

SPECIFICATIONS

A discussion of the proposed "Hydraulic Turbine Governor Specification" (ACO 48-89), by E. B. Strowger, of the Buffalo Niagara Electric Corporation, Buffalo, N. Y., and C. L. Avery of Woodward Governor Company, Rockford, Ill., was presented at this session. In addition to a detailed explanation of certain parts of the proposed standards, the paper also included a correlation of the terms defined for hydraulic turbines with those defined for steam turbines, and directions for obtaining data and calculations of regulation characteristics.

The joint AIEE–American Society of Mechanical Engineers committee on recommended specifications for prime mover speed governing appointed a joint subcommittee to draw up "Recommended Specifications for Speed-Type Governing of Hydraulic Turbines Intended to Drive Electric Generators" (ACO 48-5). This paper outlined minimum functional characteristics which generally are recognized as being necessary for satisfactory and acceptable speed governing of hydraulic turbines. Definition of terms and equipment, specifications of standard equipment and practices, optional equipment, and performance constituted the main work of the subcommittee.

In presenting his paper, "Precise Turbine Governor" (48-90), Henry E. Warren (A '02) of the Lombard Governor Corporation, Ashland, Mass., described the use of conventional governors for speed and load control, and concluded that they may be considered as almost equivalent to safety devices which prevent run-a-way upon sudden loss of load. A new governor has been developed which replaces the dashpot and the load control motor with a standard Selsyn motor. With these refinements, each unit on a large System could respond immediately to extremely small deviations from exact standard frequency, and the load dispatchers would need only to subtract loss of power and control tie-line interchange.

Presentation by title was made of "Recommended Specification for Speed-Governing of Steam Turbines Intended to Drive Electric Generators Rated 500 kw and Up" (48-4), a joint AIEE–ASME committee report, which recommends practical minimum standards for satisfactory acceptable speed governing. Definition and description of terms, equipment and performance specifications, descriptive literature, and acceptance tests are included.

# Various Tripping Schemes Discussed at Conference on Substations

A great deal of interest in a-c versus low-voltage d-c tripping was in evidence at the conference on substations which was held Friday morning during the AIEE winter general meeting in Pittsburgh, Pa. The session sponsored by the AIEE substation committee was developed to bring various methods of tripping to light. Approximately 60 people attended the session which was presided over by G. S. Whitlow (M '39) Union Electric Company of Missouri, St. Louis, Mo.

AUTOMATIC TRIPPING WITH A-C CONTROL

The problem of control power supply in the design and application of automatic tripping and reclosing of high-voltage circuit breakers for sectionalizing one or two lines at a remote unattended station without the use of a control battery was discussed in a paper called "Automatic Tripping and Reclosing of Circuit Breakers for Line Sectionalizing With A-C Control," by C. E. Winegartner (M '28), and H. E. Bonheimer (A '39), both of Cleveland Electric Illuminating Company, Cleveland, Ohio. The control and tripping scheme for two 34.5-kv oil circuit breakers uses a-c tripping and reclosing power supply, for automatically sectionalizing and re-energizing the overhead portion of two underground cable circuits, when faulted. The use of a-c tripping at a remote unattended station with control panels in a small sheet steel building, normally unheated, eliminates the hazards and difficulties of battery maintenance under these conditions. A description was given covering the operation of the various control devices for manual and automatic switching during fault conditions. It was pointed out that the use of circuit opening relays and tripping transformers, while not generally used, have proved satisfactory in service. Improvements in this a-c tripping could be obtained if a network transformer were developed into which the 3-phase currents could be fed, the output of which would feed through circuit closing relay contacts to one trip coil. This would reduce the number of trip coils required and reduce the objection to relay contacts in the current circuits. The use of rectifiers to close a-c solenoid-operated circuit breakers from an a-c source is common. However, a compressed-air-operated circuit breaker is to be preferred because of air storage for several reclosures in case of loss of a-c supply, and for faster reclosing. However, a-c operated exhaust valves are not available on these mechanisms. Development of such valves or provisions for operating them direct from the trip bar would give added stimulus to a-c tripping and reclosing.

SCHEMES FOR SMALL STATIONS

The problem and expense of maintaining a battery at small unattended stations has prompted the development of several forms of a-c tripping circuits for circuit breakers. A paper covering most of the methods of a-c tripping that have been used by the Southern California Edison Company was "A-C Tripping Schemes for Small Stations," by C. Lowerison (A '46) Southern California Edison Company, Ltd., Los Angeles, Calif. Experience with the methods described has been satisfactory, and the author points out there is a definite but limited field where a-c tripping may be used with greater reliability than that which may be expected from d-c tripping. Among the methods described were the following:

*Series or Plunger Tripping.* This method of tripping has been used extensively on stub feeders where time delay is not required. Though several methods of obtaining time delay by use of dash pots, bellows, and so forth, have been tried, experience has shown them to be unreliable. In practice the series or plunger trips are used strictly as an instantaneous relay. If time delay is necessary, some other method of tripping is used.

*Tripping Reactors.* The reactors installed in the secondary of a current transformer circuit produces a voltage drop which is used to trip a circuit breaker when overcurrent relay closes its contacts. Experience with this form of tripping has not been entirely satisfactory. The scheme uses six current transformers, three for overcurrent detection, and three for tripping. The necessity of using six current transformers is expensive.

*Holding and Tripping Coils.* Two coils are wound in opposite directions around the trip plunger so that they normally produce a cancellation field. When the overload relay operates, the relay contacts short-circuit out the holding coil and allow the short-circuit current to operate the trip plunger. In applying this method of tripping a precaution must be taken. As most oil circuit breakers are equipped with 5-ampere trip coils, one must be sure that at minimum trip value of the relay there will be at least five amperes in the current transformer secondary. This requires the use of special current transformers in some applications.

*Potential Transformers.* Several schemes of sensitive ground protection have been developed. All the methods in use involve the control of ground current to very small values and the use of sensitive equipment for detecting ground current. On most of the oil circuit breakers where sensitive ground protection is installed, 115-volt a-c trip coils, are used. Because the flow of ground current is controlled and held at very small values, the voltage dip resulting from a ground fault will be negligible. Tripping from the residual relay therefore can be accomplished reliably by the use of 115 volts through the relay contacts. Voltage source usually is obtained by connecting a single-phase potential transformer across any two phases of the line which is being protected.

SMALL DISTRIBUTION SUBSTATIONS

A number of nonbattery tripping schemes were covered in a paper called "Methods of Tripping Circuit Breakers in Small Distribution Substations," by M. E. Reagan (F '41) Westinghouse Electric Corporation, East Pittsburgh, Pa. A scheme in which the tripping energy comes from the transformed fault current is perhaps the most common type used. By the use of suitable induction relays, time delays are used to co-ordinate the over-all system relays. Current transformers are used in the higher voltage circuits over 600 volts. Energy storing devices, such as capacitors and inductors, are also in common use. Under normal conditions, energy is stored so that it is available when a fault occurs and the line voltage may be too low to operate reliably. These

devices usually are used to operate shunt trips or to trip a spring which has been charged with energy. When used with reclosing circuit breakers, it is important that the scheme permits time to recharge the storage means before closing the circuit breaker. Low-voltage trips, both instantaneous and time delay types, are used successfully in many applications. Where loads should be disconnected on a momentary loss of voltage, the instantaneous type is used. Where outages may be avoided by delaying the opening of a circuit breaker to permit a branch fuse to disconnect a troubled section, or where the load will permit a short time interruption, the time delay design is applied. Capacitors are the usual storage units used in the time delay type. There are many types of reclosing cycles in use today. They co-ordinate the fault detecting relays, the reclosing timing schedule, and the tripping device. One popular arrangement consists of using both instantaneous and time delay overcurrent relays, a reclosing relay, and a capacitor-type shunt tripping device. The reclosing relay has a cycling schedule of one instantaneous and one timed reclosure to a lockout. The object is to minimize service outages. The cycle is arranged to get rid of the fault if it is on a branch circuit so that normal service may remain on the other branches. If the fault is permanent and on the main feeder lines, lockout should result. Experience has shown that more than 80 per cent of faults are self-clearing, and so in four out of five instances, only momentary service interruptions result. As with a-c circuit breakers, the three main tripping schemes of series, storage, and low-voltage devices are used with d-c circuit breakers. In addition, short-circuit detector relay systems are used not to trip on overloads, but to open the feeder circuit breakers only on short circuits. It is possible to have a condition where a short circuit at the end of the feeder will cause less current flow than the heavy accelerating loads near the feeder circuit breaker. To give this type of selectivity, an impulse coil (a current transformer with an air gap in its iron circuit) is used. The secondary current rate of rise is measured by suitable relays to distinguish short circuits from legitimate loads.

"Fundamental Tripping Schemes," by K. B. Hoffman (M '41) Consolidated Edison Company of New York, Inc., New York, N. Y.; and "Co-ordination of Protective Devices for Control of Power Circuits," by J. R. Palmer also were presented at this session.

## Friday Session Considers Servomechanisms and Measurements

On Friday, January 30, of the AIEE winter general meeting in Pittsburgh, a session was held concerning the subject of servomechanisms and measurements. Presiding jointly at this session were E. I. Green (F '46) Bell Telephone Laboratories, Inc., New York, N. Y., and J. B. Russell (M '41) Columbia University, New York, N. Y.

### ANALOGUE COMPUTER STUDIES

Analogue computer studies of "The Effect of Coulomb Friction on the Performance of Servomechanisms" (48-84), were given by G. D. McCann (M '44), F. C. Lindvall (F '43), and C. H. Wilts, of the California Institute of Technology, Pasadena, Calif. Three basic types of systems were studied and equations derived in terms of a dimensionless parameter called "the friction ratio" which relates the friction force or torque to the disturbance. Such equation must be defined specifically for each case in question. The various effects of coulomb friction on the three systems under varying conditions were described and analyzed.

### GRAPHICAL ANALYSIS

Walter R. Evans (A '42) of Washington University, St. Louis, Mo., then presented "Graphical Analysis of Control Systems" (48-85). After a review of fundamentals, the author proceeded to demonstrate some graphical methods for finding the transient response of a control system. The basic procedure is to find the roots of the differential equations which correspond to the exponential transient terms which dominate the response. It may be applied to higher order systems or ones in which only empirical frequency data are known. Illustrative examples were given.

### RELATION BETWEEN ELECTRICAL AND MECHANICAL PARAMETERS

In his presentation of his paper, "Relation Between Electrical and Mechanical Parameters of a Permanent-Magnet Movable-Coil Instrument Having a General Circuit" (48-94), W. N. Goodwin, Jr. (F '13) of the Weston Electrical Instrument Corporation, Newark, N. J., pointed out that in the theory of electromechanical oscillating systems, mechanical parameters appear to an external driving source as an electrical impedance. The mathematics were developed for determining the values of the undamped period, specific damping coefficients, moment of inertia, spring stiffness from measurements of apparent resistance, inductance, and capacitance at the terminals of the instrument containing an unknown noninductive resistance network by a special bridge and oscillator method. If the circuit network is known, other parameters may be derived by the mathematics given in the presentation.

Established methods of making bridge measurements on a sound transducer led to the development of a similar test procedure with "A Bridge Method for Determining the Motional Characteristics of Permanent-Magnet Movable-Coil Instrument Mechanism" (48-67), which was described by R. W. Gilbert (A '36), of the Weston Electrical Instrument Corporation, Newark, N. J. Because the previous paper had developed some of the basic mathematics, the author limited his presentation to the method of measurement, supported by theoretical description as required. Accuracy with this bridge is primarily a matter of desire and design; the over-all operating accuracy of the model can be kept within 0.5 per cent of the measured values.

## Synthetic Crystals Are Subject of Winter Meeting Session

The subject of synthetic crystals was considered at a technical session on January 30, the last day of the winter general meeting in Pittsburgh. This session was sponsored by the late R. G. McCurdy (F '34) who was with the Bell Telephone Laboratories, Inc., New York, N. Y.

### CRYSTAL FILTERS

"Crystal Filters Using Ethylene Diamine Tartrate in Place of Quartz" (48-86), for use in telephone cables were described by E. S. Willis (A '45) of the Bell Telephone Laboratories, New York, N. Y. The impending shortage of quartz imports and the necessity of stepping up expansion of long distance telephone facilities prompted the development of substitutes for the 56-kc pilot pick-off filters and channel filters. Although simpler in structure and different in design, the new filter is mounted interchangeably with the old quartz filters.

### EDT CRYSTAL UNITS

"Design and Performance of Ethylene Diamine Tartrate Crystal Units" (48-87), was described by J. P. Griffin and E. S. Pennell, of Bell Telephone Laboratories, Murray Hill, N. J. The cutting of the *EDT* crystals is much like that of quartz, although cutting and processing procedures have been adapted especially to this material. Like quartz, the electrical characteristics of an *EDT* crystal plate vary with its angle of cut and dimension ratios. The various resonances which occur in a crystal plate in response to an electric stimulus were described and several reactance spectrums shown. Temperature coefficients, which for useful cuts is a concave downward parabola, are comparable to quartz. Assembly techniques and testing equipment were described.

The discussion of the *EDT* crystals was completed by A. C. Walker and G. T. Kohman, of the Bell Telephone Laboratories, Murray Hill, N. J., in their paper "Growing Crystals of Ethylene Diamine Tartrate" (48-88). The basic salt is prepared by adding solid crystalline tartaric acids to a solution of ethylene diamine in water. The spontaneous crystals from this solution are removed for seeds and to make the controlled supersaturated solution. Careful control of the degree of supersaturation and the circulation of the solution around the growing crystals is attained by fastening the crystal seeds to a spider which is rotated with a reciprocating motion through the saturated solution. Practices which control crystal growth, experiences gained to date, and certain characteristics of the crystal were described.

# System Engineering Session Discusses Frequency and Voltage Reduction

A number of interesting topics were considered at the general system engineering session which was held Friday afternoon during the AIEE winter general meeting in Pittsburgh, Pa. Included on the program was a discussion of electric power and our national defense, as well as a symposium on controllable factors affecting system loads which included four conference papers mainly devoted to the consideration of frequency and voltage reduction as a means of handling emergency capacity conditions. J. E. McCormack (F '44) Consolidated Edison Company of New York, Inc., New York, N. Y., presided over the session.

### POWER AND NATIONAL DEFENSE

"Electric Power and Our National Defense," was presented by W. L. Cisler (M '35) of the Detroit Edison Company, Detroit, Mich. The author pointed out the close connection between electric power and our national defense, and strongly emphasized the need for cooperation between the electric power industry and the Department of National Defense. He outlined a program to bring about constructive results designed to help maintain the United States' industrial capacity in time of war. The full text of the paper appears in this issue of *ELECTRICAL ENGINEERING* (*pp 319-24*).

### FREQUENCY AND VOLTAGE REDUCTION TESTS

In 1947 the Kansas City Power and Light Company made some interesting tests on the effect of lowering frequency and voltage on an isolated system, and the results were presented in the paper called "Results of Frequency and Voltage Reduction Tests on an Isolated System," by C. B. Kelley (M '30) and T. W. Schroeder (M '44), of the United Light and Railways Service Company, Davenport, Iowa. The Kansas City Power and Light Company was faced with the problem of a potential shortage generating capacity caused by the inability to secure added generating capacity during the war years and the unprecedented growth of system load following the close of the war. In addition, the inability during the war to remove generating equipment from service for the usual overhauls resulted in the need for a program of scheduled outages for maintenance. Under these conditions, together with the anticipation of still further load increases, it was decided in the early part of 1947 that emergency conditions might require the lowering of system frequency and voltage. To determine the amount of relief that could be expected from these expedients, tests on the system were conducted to measure the amount of load decreases that would obtain for a given drop in system frequency and voltage. The system consists of two steam plants whose total generating capability is approximately 272 megawatts, and a load whose character is 44.7 per cent industrial, 14.6 per cent domestic, 27.1 per cent commercial, 7.7 per cent d-c Edison system, and 5.9 per cent consisting of other utilities. The tests were performed by dropping the system frequency gradually in approximately uniform steps over the period of the test. Prior to voltage dropping, test men were stationed in those substations having feeder voltage regulators to make the regulators nonautomatic at a given time. Immediately following this the generating plant voltage was dropped in approximately uniform steps by simultaneous changes in setting of the generator voltage regulator. Voltage was held at test values under guidance of a portable indicating voltmeter. System load readings were taken from a Leeds and Northrup strip-chart totalizing recorder which totalizes the output of each generator on the system. Frequency readings were taken from a Leeds and Northrup frequency recorder. A summary of the test results was given as follows:

> During the first test, February 20, 1947, with the system load fairly steady at 214 megawatts and normal frequency of 60 cycles, the frequency was dropped gradually over a 15-minute period to 58.5 cycles and the load dropped 204 megawatts. This represents a frequency drop of 2.5 per cent and a corresponding load drop of 4.68 per cent; or about 1.87 per cent load reduction per per cent frequency reduction; or approximately 0.31 per cent per 0.1-cycle frequency reduction. On March 7 during the second test the same system was tested to determine the effect of dropping voltage and also the effect of dropping frequency under lower than normal voltage conditions. With a load of 225 megawatts and normal voltage, the voltage was dropped three per cent below normal and the load decreased to 218 megawatts, one per cent load decrease for one per cent voltage decrease. With the voltage three per cent below normal and the load of 218 megawatts, the frequency was dropped one cycle and a further load decrease of 6.5 megawatts resulted, or about 1.78 per cent load drop per per cent frequency drop under the reduced voltage condition. The results of the test indicate that system load reductions can be effected safely by lowering system generated voltage and frequency. It should be possible to lower the system primary voltage as much as five per cent, and at the same time decrease the system frequency 1½ cycles, in which instance a reduction of nine per cent could be effected provided the regulators in the substation are set on nonautomatic. If the regulators are not set in this manner, the per cent drop in load would be in the order of 0.3 to 0.6 per cent for each one per cent drop in voltage.

### EFFECT OF REDUCTIONS

The final paper in the session was "Technical Approach as to the Effect of Voltage and Frequency Reductions on System Load," by J. E. McCormack (F '44) Consolidated Edison Company of New York, Inc., New York, N. Y., who presided at the session.

The tight capacity situation in the utility industry has made load reduction in emergencies a matter of increasing interest. All operators are in substantial agreement as to the effectiveness of voltage reduction but there is considerable disagreement as to the effect of frequency reduction. The paper pointed out the effect of frequency reduction on components of load, as well as of the system itself, to stimulate discussion of the subject. The effect on utilization devices of frequency reduction without change in voltage varies considerably with the device. The power consumed by an incandescent lamp is independent of frequency whereas the power consumed by fluorescent lamps with their ballasts is not. Tests on single lamp fluorescent fixtures showed a marked increase in watts with reduced frequency while double lamp fixtures showed no appreciable change in wattage with reduced frequency. Motors operate at reduced speed with reduced frequency resulting in reduced work performed and reduced wattage. However, motors subject to intermittent operation such as domestic refrigerator and oil burner motors will perform the same amount of work over a period of time. The effect of reduced frequency on a large group of such motors is to provide load relief for a short period of time.

Over a longer period the demand of the group of motors actually will exceed that at normal frequency because of somewhat reduced efficiency. As the magnitude of the components of system load generally are not known it is impossible to predict accurately the effect of frequency reduction on a system's load. Most systems operate as part of an interconnection which makes load reduction by means of frequency reduction difficult. Attempts to reduce frequency on a part of such an interconnection serves to transfer load to the remainder of the system and obtain relief only at the expense of the remainder of the interconnected system. Frequency reduction affects the electrical characteristics of components of the system in that line and transformer reactance is reduced. This may act to increase the system load by reducing voltage drop and thereby increasing the voltage at the utilization point. Speed reduction of generating plant auxiliaries may reduce the capability of the plant where the capacity of auxiliaries is the limiting factor. Practically, it is difficult for a system to reduce frequency without simultaneously reducing bus voltage as a result of speed reduction of the exciters. This, of course can be corrected by the operating personnel. It is possible that in some instances apparent reduction in load resulting from frequency reduction actually is the result of the accompanying voltage reduction. If this is the case it would appear more advisable in most instances to obtain the load reduction directly by voltage reduction, maintaining normal frequency.

Also presented at this session were "Operating Tests of Voltage-Load Reductions," by D. P. Reed, New England Power Company, Boston, Mass.; and "Voltage and Frequency Reduction as Tools for Handling Emergency Capacity Conditions," by H. W. Phillips, Pennsylvania-New Jersey Interconnection, Philadelphia, Pa.

# Two Winter Meeting Sessions Devoted to Industrial Control

Industrial control was the subject of two sessions during the 1948 winter general meeting in Pittsburgh; one on Monday and the other on Friday. Both were presided over by J. D. Leitch (M '42) Electric Controller and Manufacturing Company, Cleveland, Ohio.

### LIQUID RHEOSTATS

The opening paper of the session, "The Liquid Rheostat for Speed Control of Wound Rotor Induction Motors" (48-98), by G. L. McFarland (M '46) and W. M. Alvarez, of the General Electric Company, Schenectady, N. Y., presented the basic design considerations for modern liquid rheostats and their control systems. Liquid rheostats (metal electrodes in a tank of electrolyte—such as a few per cent of sodium carbonate in clean water) especially are suited to speed control systems because of their inherent ability to provide stepless control with minimum maintenance and maximum dependability. Resistance properties for the electrolyte depend upon the concentration of sodium carbonate, solution temperature, and current density at the electrode. Because of the definite negative temperature exhibited by the electrolyte, cooling is of prime importance. Cooling coils within the rheostat are cheapest but do not give minimum size. Forced circulation of the electrolyte with an external liquid-to-liquid heat exchanger results in minimum rheostat size and facilitates control and maintenance. Various types of load were discussed and control systems evaluated. Simplest and often adequate is manual control for the rheostat pilot motor (which varies electrode spacing). Amplidyne speed- or torque-sensitive system offers precise and constant control.

"A New Liquid Rheostat," was discussed by T. B. Montgomery (M '41) and A. C. Halter (A '40), Allis-Chalmers Manufacturing Company, Milwaukee, Wis. Conventional liquid rheostats or slip regulators vary the resistance between electrodes by changing either the area between points of applied voltage or by changing the length of path between these points. The most common type has a constant electrode area with simultaneous movement of three electrodes to vary length of path through the electrolyte. A large speed range only can be obtained by increasing the distance between electrodes. Consequently, this means a larger rheostat and also a large electrode travel to make a small speed change at low speeds. The electrodes must be very close together for the low resistance position. Entrapment of gas bubbles formed by hydrolysis between electrodes forms an insulating layer, causing overheating of current carrying portions of the electrodes and electrolyte "hot spots." A second type of conventional liquid rheostat utilizes a constant length conducting path and varies the conducting area by raising and lowering the electrodes. A much better speed versus electrode travel curve can be obtained with this type as the contour of the electrodes may be designed to give varying differentials of area per unit of travel. The vertical electrode surfaces facilitate electrolyte flow and insulated areas and "hot spots" caused by collection of gas bubbles are avoided. However, vapors rising from the surface of the electrolyte, between the electrodes, lowers the dielectric strength to a point where arcing and flashover between electrodes may occur. The new liquid rheostat has the advantages of both types and many disadvantages have been eliminated. Electrodes for each phase are mounted in separate cells of insulating material. At one end is mounted the stationary electrode which extends nearly the full length of the cell. At the other end of the cell is a movable weir to which is mounted a smaller electrode, slightly below the electrolyte level. Electrolyte is pumped at a constant rate through insulating tubes to the three cells, passing out through the weirs to a common reservoir. Operating mechanism varies level of weir—and consequently movable electrode position and electrolyte level. The electrodes intermesh at the upper position to give low resistance with adequate spacing. Electrode contour may be varied as required to give any motor resistance versus electrode travel curve desired, from the straight line curve required for constant torque drives to a highly varying degree of resistance change with change in rheostat position desirable from applications such as fan or pump drives. Equal speed change per unit of rheostat travel insures equal accuracy throughout motor speed range. Possibility of flashovers between electrodes is eliminated by keeping one electrode always below the electrolyte level. Wide resistance change for small electrode travel and liquid-to-liquid heat exchanger keep rheostat size down (350-horsepower, 80-per-cent speed reduction unit, 26 inches by 36 inches by 67 inches high).

"Improvements in Rolling Mill Preset Screw-Down Controllers" (48-11), were described by J. D. Leitch and C. A. Schurr (M '47) of The Electric Controller and Manufacturing Company, Cleveland, Ohio. The automatic preset screw-down controller using differentially driven control elements has additional developments to insure accuracy of settings at higher screw-down speeds. Electronic balance detectors replace polarized contact-making ammeters while balance anticipators permit the introduction of slow-down motor circuits for accurate stopping.

### CONTROL PRACTICES

A description of "Steel Mill Control Practices and Trends," was presented by A. W. Schmitz of the General Electric Company, Schenectady, N. Y., at the Friday afternoon session. The electrical manufacturer who builds motors and controls today continuously is confronted with new requests to provide more and more automatic control with its endless chain of operating and self-regulating functions. These requests are initiated by the ever-increased demands for higher and higher mill speeds, greater rates of acceleration and deceleration, closer operating accuracies, and faster and faster response. Steel mill control is grouped essentially into three basic classes of application: auxiliaries, processing lines, and main roll drives. The controls for these applications have many variations, not only in electrical, but also in mechanical requirements. The complexity increases with the number of electrical functions.

Mill-type auxiliaries, which consist essentially of single motor drives independently operated, are used extensively in numerous places. Constant voltage control is used to a large extent while adjustable voltage amplidyne-type control is used frequently on the more important applications, where fast repeated operating cycles are required. Processing lines perform several operations in one continuous process when manufacturing strip steel. Annealing, plating, cleaning, and galvanizing are typical examples of such processes. Adjustable voltage control is used nearly always on these lines to obtain the maximum speed range, and also provides the required flexibility to operate certain portions of the line at different speed levels by supplying power to prearranged groups of motors from separate and independently controlled generators.

Main roll drives refer to metal reduction mills, either of the hot or cold rolling type. The adjustable voltage amplidyne-type control finds its greatest use on these drives because of its maximum operating flexibility and inherently fast response. The range in motor horsepower requirements on main roll drives varies extensively and goes into the thousands of horsepower. Depending upon the type of drive, the control may include any one or a combination of the following control functions: voltage regulation, speed regulation, current regulation, tension regulation, and position regulation. Each of these functions incorporates definite protective control limits and always the required system stabilizing features.

In the matter of trends, more and more time and study are allocated towards control improvement. Control devices, circuits, and whole control systems are continually under investigation to obtain further refinements in performance and simplicity. In many instances, critical operating requirements are simulated in manufacturers' laboratories to predetermine the performances of a device circuit or system. Amplidyne control now is furnished in packaged form which provides many desirable features from the standpoint of standardization and ease of adjustment. A new regulating control system of the amplidyne electronic type has been developed. This control operates with or without the electronic amplifier,

which will minimize, if not completely eliminate, many of the objections expressed by the mill operators—unfamiliarity with electronic circuits, tubes, and the like. The electronic amplifier is of a unit packaged drawout type. This provides maximum flexibility for quick change. Such a feature allows the maintenance man, in case of failure, to disconnect the electronic control quickly and continue operations or insert a spare unit without shutdowns.

### OVERLOAD RELAYS

The comparative merits of "Two Overload Relays Versus Three on 3-Phase Systems," was considered by Kennard Pinder (F '45) E. I. du Pont de Nemours and Company, Inc., Wilmington, Del. For many years there was a difference in the number of overcurrent relays considered necessary for overcurrent fault protection of 3-phase circuits. Today, standard practice and code requirements call for an overcurrent device in each ungrounded conductor of a circuit regardless of the type of system employed. However, the number of overload relays or trip devices to employ in a motor controller is a moot question. Many engineers think of 2-coil overload relay protection as adequate for all installations of 3-phase motors. Section 4327 of the 1947 edition of the National Electric Code lists the minimum allowable number and location of overcurrent units, such as trip coils, relays, or thermal cutouts, to be employed for motor running protection. Two-element overload relay protection fulfills the requisite for 3-phase motor protection regardless of the type of supply system used, and, as a result, controllers with only two overcurrent units are standard in the control industry today.

Every year many hundreds of thousands of motors are installed in industry to drive machinery. The success of their installation is dependent upon the proper selection and correlation of the motor to the driven machinery and of the motor to the controller and system wiring. The function of the motor controller is not only to act as a starting and stopping means and to protect against overload under normal operating conditions, but also to provide protective features against abnormal situations which may exist in the power supply.

The purpose of Mr. Pinder's conference paper was to discuss fault protection for circuits and motors, to outline and show some applications and conditions of operation where two overload relays do not provide adequate protection, and to recommend the use of three overload unit protection, or its equivalent, where the chances are one in three that protection will not be obtained with two overload relay equipment. He emphasized the fact that his discussion applies to overcurrent fault protection and not to protection against actual overload caused by the driven equipment.

### HEAVY DUTY CONTACTORS

"Heavy Duty Contactors, 6,000 Amperes, 3,000 Amperes, and 1,500 Amperes," were the subject of R. M. Peeples (A '45) Allis-Chalmers Manufacturing Company, Milwaukee, Wis., and C. R. Peter (A '44) of the Allis-Chalmers Company, West Allis, Wis. A new heavy duty contactor recently was designed and put into service on steel rolling mills in higher ratings than ever were built as standard contactors. The new contactors are produced in type 311, of 1,500-ampere rating, type 312 of 3,000-ampere rating, type 313 in a 6,000-ampere continuous rating. The new contactors are intended to apply in the large motor field and already have been put into operation on hot mills and cold reduction mills in single armature circuits up to 3,500 horsepower and 750 volts. The new design is the result of extensive shop study and test on high current interruptions; many features being designed from this study. These include the shape and design of contacts, arc box, and arc handling assemblies. Features of the contactor include a series continuous duty blowout coil wound of strap copper on edge, forged copper contact assemblies, heavy duty silver insert contacts, and a new mounting arrangement consisting of steel bars wrapped with paper base phenolic to which the stationary and movable contacts are clamped. The contactor construction allows shipping and storing without the customary panel backing and provides for mounting on open angle iron framework, mounting dimensions for all sizes of contactors being the same. The operator of the contactor is a heavy duty specially designed solenoid arranged for intermittent coil duty and provided with slot laminations in the iron structure for high speed operation. Contactor pressures attained with this solenoid are 300 pounds on the 6,000-ampere size and 150 pounds on the 3,000-ampere and 1,500-ampere size. Application of the contactor has proved especially easy because of the design of the mounting features. Open-type frameworks mounting the dynamic braking resistors and other accessories for line control of a single motor have proved most popular. Duplex arrangements with small control relays on one side of the panel structure are another popular arrangement. Job engineers have been able to group these contactors in a compact design rendering a considerable saving in bus work and space.

### POWER FUSES

"High-Voltage High-Interrupting-Capacity Controllers With Current-Limiting Power Fuses," was presented by E. H. Alexander (M '43) General Electric Company, Schenectady, N. Y. A complete assemblage of devices into a co-ordinated high-voltage high-interrupting-capacity motor controller can be broken down into several simple elements for a study of their behavior under short-circuit conditions when protected by the current limiting power fuse. Outside of the fuses themselves, the elements are the busses, bus supports, vertical bus riser, current transformers, overload relays and switching mechanisms. Because the duration of the short circuit is so extremely small, busses which are capable of withstanding the mechanical forces automatically will withstand a thermal burden imposed on them. The formula for determining the force per unit length on busses and bus risers is well established. The current transformers need to be given special consideration in order that they might have sufficient mechanical strength to withstand the electromagnetic forces of short-circuit current. Standards for the mechanical limits of current transformers have been published by the American Standards Association (number 57.1), and the AIEE (number 11). The overload relays providing motor-running overcurrent protection are considered with respect to their time versus current characteristics. One application practice in designing a co-ordinated control is that no fuse shall blow under any normally expected condition of operation of the motor and shall blow only under short-circuit conditions. This means that the overload relay time versus current characteristic must be co-ordinated carefully with the melting time of the fuse so that under locked rotor conditions, the overload relay always will trip before a damaging temperature rise occurs on the silver wire in the fuse. Consideration also must be given to the widely different values of short-circuit current which may flow. The fuse must give successful performance for any value of current, say, in excess of ten times the full load current of the motor. Up to ten times full load current of the motor, the thermal overload relay should open successfully the circuit control before the fuse is damaged and the switching element successfully should interrupt ten times the full load motor current for which it is recommended. The final circuit element in the controller to be considered is the switching element or the contactor itself. It is assumed that the contactor is capable of interrupting ten times the full load motor current for which it is recommended as this is the requirement of any National Electrical Manufacturers Association rated contactor. When a contactor whose interrupting rating does not exceed ten times the normal motor current rating, is used in conjunction with a current-limiting fuse, the momentary current through the contactor greatly exceeds ten times the normal rating and the electromagnetic forces exerted upon the contact tips shunts and supports vary as the square of the current through them. Under these conditions of extremely high


**AIEE PROCEEDINGS**
**Fourth Order Form**

**The fourth AIEE PROCEEDINGS order form appears on pages 49A and 50A of the advertising section of this issue. These PROCEEDINGS are the technical papers presented at the 1948 winter general meeting in Pittsburgh, Pa., January 26–30, and may be ordered in accordance with instructions on the order form.**

current of short duration the tips of the contactor will separate as a result of the electromagnetic forces and a small amount of arcing will occur at the tips. The duration of this arcing is exceedingly short because of the fast action of the fuse which limits to a marked degree the energy released in the arcing of the contact tips of the contactor. A detailed description of the mechanical construction features and the electrical characteristics of the current limiting motor starter fuse also were given.

# Session Considers Various Aspects of Use of Electric Cables in Mines

Six conference papers discussing the use of electric cables in mines formed the basis of a technical session on Friday, January 30. The chairman at this session was AIEE Vice-President E. W. Davis (F '34) Simplex Wire and Cable Company, Cambridge, Mass.

### USE AND INSTALLATION

The "Safe Use and Installation of Trailing Cables in Coal Mines," was discussed by Thomas R. Weichel (M '46) Bureau of Mines, Mount Hope, W. Va. In the early days of mining, electricity was not instrumental in the mining of coal or other minerals. Gradually, however, steam-driven hoists, pumps, and ventilating fans were converted to electric drive, and electrically driven haulage equipment installed. Eventually, the electric transmission cables were extended to the working places, and electrically driven machines were enlisted to drill, cut, and load the product. With increased electrification, many serious problems were encountered because of the destructive effects on the cable produced as a result of excessive overload currents, as well as the severe conditions imposed upon equipment in the mining industry. In the past three decades, a great number of mine fires have been started by the ignition of the combustible conductor installation and outer covering of trailing cables, fires which were extremely difficult to combat and extinguish owing to the irritating and noxious gasses, fumes, and vapors which result from the evaporation, distillation, and combustion of the sundry compounds used in the construction of cables.

In the search for safe practices in the employment of trailing cables in mines, a number of important points should be taken into consideration. The cable should be adequate for the service intended, and the current carrying capacity of the power conductor should be sufficient to handle the load without overloading and overheating the cable. Splices should be made strong electrically and mechanically and they should be well insulated with insulating materials suitable for the particular type of cable. Conductors should be spliced or joined as to be mechanically and electrically secure without solder, and, unless an approved splicing device is used, then should be soldered with a fusible metal or alloy, or brazed or welded. Trailing cables should be stored in long, loose loops rather than piled in tight coils, or the cable should consist of short sections that can be added as required. Good voltage should be maintained at all working sections underground so as to obtain maximum efficiency of the equipment and cables supplying power to the equipment. The trailing cables should be protected by a fuse or circuit breaker at the power tap, and flame-resistant-type cables should be used wherever practicable.

### MACHINERY MANUFACTURER'S VIEW

The point-of-view of a machinery manufacturer was represented by Frank R. Hugus, Joy Manufacturing Company, Franklin, Pa., in his conference paper, "A Machinery Manufacturer Looks at Cable." The primary quality that a coal mining machinery manufacturer requires in a cable is that this cable give satisfactory service when used under extremely bad operating conditions. A cable is only an insignificant part of an expensive piece of equipment and must be able to give the same rugged service as is rendered by the complete machine.

Mining machine cables must be constructed to operate under conditions of moisture, mild acids, heat, ozone, oil and grease, arcing, neglect and indifference, and many other unfavorable conditions. Specifically, trailing cables are run over by rubber-tired shuttle cars, caterpillar-mounted loading machines and trucks, and track-mounted equipment. Sometimes this is accidental but, as often as not, it is the result of plain indifference on the part of the machine operator. Trailing cables also are subjected to constant flexing, abrasions, tearing, and jerks and pulls. Mr. Hugus reported recently receiving a report which stated the copper in a trailing cable had elongated ten per cent. This means that this cable has approximately 300 feet of insulation and jacket on approximately 330 feet of copper conductors.

Under such operating conditions cables do not have very long lives. In some mines a cable may be in service only a few days until it is necessary to repair some damages to it. Under the most desirable operating conditions if a trailing cable can be repaired and kept in service for five years the users feel that they have secured satisfactory life. Most specifications and standards for rubber-covered cables in existence today are based on an anticipated life of more than five years. The application of such standards to cables for mining machines is misleading.

The author expressed the belief that there is a definite need for specific standards covering cables designed for mining service. These, he said, should give due consideration to the exacting operating conditions encountered in a mine and an effort should be made to correlate the considerations of power loss, voltage drop, normal wear, and life of the cable.

### IMPROVEMENTS

The necessity for increased safety in coal mines, particularly the gaseous mines, has resulted in new types and designs of trailing cables differing in many respects from the conventional prewar types. In "Improvements in Mining Machine Cables," R. A. Schatzel (A '28) Rome Cable Corporation, Rome, N. Y., reviewed briefly these changes insofar as cable performance, application, and life are concerned, together with a comparison with modern American mining cable practice in England. Greatly added protection against cable fires has been brought about by the incorporation of flame-resistant materials in the cable construction, and greater protection against electric shock, particularly for off-track equipment, has been established by the new Federal Mine Safety Code which requires the use of a separate grounding conductor on all new equipment.

Failure can be created by direct copper-to-copper contact resulting in a low resistance short circuit which yields a maximum current flow as limited only by the impedance of the circuit, or it may be caused by a high resistance short circuit which is the predominating type of failure and is the most difficult to locate. In either case, the automatic circuit breaker arrangement using pilot wires and the instant trip feature is excellent protection to limit fault damage at an incipient failure. British authorities claim that, because of the fiery nature of their coal mines and the very hazardous conditions resulting from their thin coal seams, higher voltages, and the like, their cables get more severe treatment than in the United States, and consequently must be designed safer and with greater caution.

Because mine cables perform the most difficult service of any electric line, a greater mechanical safety factor is necessary for their satisfactory operation. Mr. Schatzel pointed out that consideration of these factors in design will result in improvement of cables and be found to be good safety practice as well as good economy.

### ESSENTIAL CHARACTERISTICS

"Essential Characteristics of Design and Materials for Mine Trailing Cables," were discussed by G. J. Crowdes (F '46) Simplex Wire and Cable Company. He pointed out that coal mining has required development of special electric cables peculiar to this branch of the industry and to fit the many special machines employed. Such cables supply power to various types of mobile and portable equipment. They consist of different combinations of flexible copper conductors, insulation, and tough outer jackets. Surveys of mine conditions have been made and the paper gave the conditions, including hazards to which the cables are exposed, and from these conditions the necessary cable characteristics.

Materials were considered in detail by Mr. Crowdes. Conductors usually are stranded from copper although steel

strands often are added to increase tensile strength. Insulating compounds, it was pointed out, must have adequate electrical properties under all conditions. As mine cables operate at elevated temperatures the electrical, and also physical, properties of the insulation are important at these temperatures. Most insulating materials show a reduction in physical properties at elevated temperatures. It was pointed out that probably the most important single property for insulation of mine trailing cables is compression resistance particularly at elevated temperatures. Data were given on five different insulating compounds showing essential physical properties. One of them is considered to be very suitable for mine trailing use. Discussion of maximum operating temperatures pointed out that recent suggestions to increase these from 60 degrees centigrade to 75 degrees centigrade cannot be considered a conservative recommendation in view of the heavy currents and high temperatures to which such cables normally are subjected.

Jacket materials were discussed and properties shown for three different rubbers, two of them synthetic. Neoprene, because of its excellent properties, is at the present time the preferred material.

In reference to cable design, conductors and the method in which the strands are assembled were considered. It further was indicated that having made proper choice of materials, it is equally important that these materials be assembled in the cable so that full advantage may be taken of their properties. Adhesion between conductor and insulation is often important, as well as adhesion between insulation and jacket and between double jackets when used. Reinforcement such as in tire treads is also of advantage in increasing resistance to compression and impact. Typical uses, service conditions or hazards, and some important design features were given for the common type of cables, as well as their general properties and any particular field hazards to which they are exposed.

Data were given on mechanical tests performed on completed cables to indicate their resistance to impact and compression. These data bring out the differences possible by choice of material and by different designs. The data show that a wide variation in these properties is possible and that proper correlation of materials and design is essential.

In conclusion it was pointed out that such studies of cables are continuing and undoubtedly will prove beneficial, and the hope was expressed that manufacturers and users will correlate careful records of the performance of various cables and freely interchange such information for the benefit of the art.

### MECHANICAL PROBLEMS

"Mechanical Problems of Trailing Cables on Mobile Mining Machinery," were covered by C. B. Peck, Jr., of Anaconda Wire and Cable Company, New York, N. Y. The need for thorough maintenance was emphasized strongly. Careful mechanical handling and thorough maintenance can do much to offset the severe service conditions under which electric cables operate in mines. Some causes of cable failure were considered. Equipment running over its own cable or that of another machine was said to be the most serious cause of cable failures. In this regard, experience has shown that the parallel-type cable is superior to either the concentric construction or the multiple-conductor round cables with conductors twisted, as far as ability to withstand the effect of crushing was concerned. Another frequent cause of cable failure is excess cable-reel tension. The tension on motor-driven reels of shuttle cars is set high so that the reel will gather in the cable fast enough as the shuttle car returns. The initially high tension increases as the reel empties, as a result of the decrease in drum diameter. Instances have been reported where the tension has stretched the copper conductors as much as ten per cent, and has changed the temper from soft to medium hard. Manufacturers of mining machinery have recognized this problem, and have developed recently a hydraulically-operated reel to assure uniform tension. Terminating the cable of a shuttle car at some intermediate point on its run, other than the discharge point, is also a cause of cable failure. This is caused by the sudden tension imposed on the cable when the car runs past the terminal point. At this point the cable reel must reverse rotation almost instantly, however, because of the inertia of the cable reel weighing some 400 pounds, it fails to do so with the result that the cable takes the strain. Under such conditions, sometimes the cable is severed completely, or, at least, greatly stretched. Attention was directed to the increasingly important problem of making proper splices in trailing cables. How extensive this problem is was indicated by the information received from one large coal company that it has made many thousand splices in trailing cable in one year. It was pointed out that cables which temporarily are spliced at the mine face, should be taken out of service as soon as possible and a permanent vulcanized splice made in the repair shop by competent workmen. Examples of how poorly splices are made in some mines were shown on slides. New and improved mining equipment, better cable, and the mine operator's constantly increasing attention to maintenance, all have resulted in lengthening the life of mine trailing cables. Probably the most important of these elements in future improvement in cable life is still greater emphasis on proper installation and maintenance. Progress in this direction is almost entirely dependent upon the greatly expanded and intensified training programs to assure correct mechanical and electrical installation and maintenance. Also presented in this session was "Discussion of Electric Cable Practice in Coal Mines of Illinois," by C. C. Conway, Consolidated Coal Company.

## Microwave Transmission Facilities Described at Radio Relay Session

Radio relay systems were the topic of a technical session held January 30, and presided over by C. E. Ports (M '34) of the Federal Telephone and Radio Corporation, Newark, N. J.

"The Philco Philadelphia–New York Microwave Television Relay System," was described in detail by W. H. Forester, of the Philco Corporation, Philadelphia, Pa. Intercity microwave relay connections are necessary for the quality and variety of programs which are envisioned for future television broadcasts. A new Philadelphia–New York television relay system will employ two relay stations at Wyndmoor, Pa., and Mount Rose, N. J. Wide-band frequency modulation will be used to transmit 4-megacycle signals simultaneously in both directions at 1,400 megacycles. Identical transmitters and receivers will be used at all four stations, a relay repeater being composed of receiving and transmitting terminal equipments. This arrangement easily is adapted to making remote pickups in areas surrounding the repeater stations and transmitting them to both terminals. Heterodyne modulation will be used at the repeater stations to transpose the radio-frequency signal to an intermediate frequency for amplification and translate it back to radio frequency for retransmission. The resultant elimination of the detector, modulator, and video circuits normally used in repeaters reduces both the distortion and the complexity of the repeater and makes it basically one long intermediate-frequency amplifier with radio-frequency mixer on each end. Such an amplifier is a relatively noncritical circuit requiring no level controls and is well adapted for unattended operation. Slides were shown of the component parts of the system. Theoretically, the 3-link 84-mile system will have an over-all signal-to-noise ratio of 45 decibels, and at present a similar temporary longer 4-hop system is operating over the same territory at about 35-decibel signal-to-noise ratio.

### PORTABLE STUDIO LINKS

Radio or special coaxial circuits must be used in most instances for transmission of on-the-spot news, sports, and other general interest pickups, said C. A. Rosencrans, of the Radio Corporation of America, Camden, N. J., in his presentation of "Portable Television Studio-to-Transmitter Links." Special portable radio transmitters and receivers previously used gave good performance but were quite cumbersome. With the war time development of the klystron a new attack on the problem was possible. It was now feasible to generate and modulate signals at frequencies of 10,000 megacycles and higher. Although the actual power available is

only a small fraction of a watt, very great antenna gains are readily obtainable. At the same time power supply requirements also are diminished, with the net result that the equipment can be assembled in packages that are portable in size and weight. The commercial results of this work are units designed to operate in a frequency-modulated system transmitting in the band between 6,500 and 7,050 megacycles. The nominal power output is 100 milliwatts—the direct output of a reflex klystron originally intended for use as a heterodyne oscillator in a radar receiver. This same klystron serves as the heterodyne oscillator in the receiving portion of the television relay system.

Physically, the transmitting equipment consists of the antenna, transmitter, and transmitter control. The antenna utilizes a paraboloidal reflector four feet in diameter and a means for mounting this assembly on a standard moving picture camera tripod. All power requirements are supplied by the transmitter control unit. In addition, the functions of modulation control, frequency adjustments, and other associated controls are directly available to the operator.

The receiving equipment has a corresponding arrangement; an antenna, receiver, and receiver control. The antenna is identical with that used with the transmitter. However, only a portion of the complete receiving system is incorporated in the receiver mount: the local oscillator, mixer, and five of the 12 intermediate-frequency stages. The interconnecting cable between the receiver and receiver control is the same special multiconductor cable used for the transmitting equipment. The receiver control incorporates only the remaining circuits associated with the receiver, the remainder of the intermediate-frequency amplifier, video and automatic-frequency-control discriminators, an automatic-frequency-control amplifier and a video amplifier, together with the necessary manual controls. The power supply requirements are met easily by a number of standard power units and so far have not been incorporated as part of the system.

This equipment is capable of an operating range of better than 30 miles over a line-of-sight path. Usually, this means that the user more often finds his range limited by the lack of a line-of-sight path rather than by limited transmitting power. The relay picture quality is excellent; a properly adjusted system is capable of transmitting a 525-line test pattern with little or no degradation.

### TWO PAPERS DESCRIBE 150-KC CARRIER SYSTEM

"A 150-Kc Carrier System for Radio Relay Applications" (48-91), was described by J. E. Boughtwood (A '41) of the Western Union Telegraph Company, New York, N. Y. Thirty-two independent voice circuits are combined by single-sideband frequency-division to occupy a frequency range of 3.9–147.3 kc. Each voice band may accommodate 18 narrow-band or 10 wide-band telegraph channels. A simpler method of translating frequencies with minimum stages and grouping filters to utilize coils of nominal efficiency rather than crystal units has proved advantageous. The modulator is of an improved balanced bridge type using small rectifying elements to perform the switching function under control of the applied carrier voltage. Tests indicate that a signal-to-noise ratio on a single channel of a completely busy multichannel telegraph system averages better than 50 decibels. Maximum frequency shift in any voice band has not been greater than one-fourth cycle per second.

R. C. Taylor (A '30) of the Western Union Telegraph Company, New York, N. Y., described the filters used in the carrier system of the previous paper in his presentation of his paper "Filters for a 150-Kc Carrier System" (48-92). All of the filters used have the relatively high ratio of upper cutoff frequency to lower cutoff frequency of approximately two. Inductance coils were limited to five in number in the lower frequency band filters because of their high cost and space consumption. Diagrams and calculations were given to show the derivation of these new filters from standard filter component and the modifications required to insure correct operation with parallel connections. Attenuation measurements show that the combined effect of dissipation and imperfect termination are about one decibel at the end of the signal spectrum in all the filters and less than one-tenth decibel in the central part of the pass band. The use of shell-type dust-core coils with heavy copper shielding provides adequate temperature and signal-level stability. Manufacture with small inductance tolerance is possible. Commerical mica capacitors which have been given an aging treatment by means of temperature cycles were used.

The final conference paper which also discussed carrier equipment used in radio relay systems was "Multichannel Carrier Telephone Equipment for Radio Link Operation," by H. R. Hunkins, of the Federal Telephone and Radio Corporation, Nutley, N. J., and E. M. Ostlund of the Federal Telecommunications Laboratory, Nutley, N. J.

## Electric House Heating Discussed at Symposium

M. M. Brandon (F '44) of the Underwriters Laboratories, New York, N. Y., presided at the January 30 session devoted to electric house heating where four papers were presented in discussion of the heat pump and one on resistance heating.

The material covered in the heat pump discussion appears elsewhere in this issue (*pp 338–45*).

### RESISTANCE HEAT TEST CONDUCTED

The final topic of the session was turned to resistance heating of homes by the presentation of "Electric House-Heating Tests in Oregon" (48-95), by W. L. Sharp and A. E. Opdenweyer (A '47), of the Portland General Electric Company, Portland, Oreg. Fifteen months of tests of approximately 50 dwellings heated by electricity have led to valuable conclusions in spite of the fact that the design temperature of 10 degrees was not reached during this time. From a standpoint of operating costs, data showed favors unit heating systems over central furnaces. The use curve given followed the shape of the degree–date curve very closely, except during the summer months. A 2-hour maximum demand period occurred in the morning, and a diversified demand at the time of system peak was about 30 per cent. The annual load factor of the installation based upon demand coincident with the system peak was approximately 30 per cent. Unlike other major appliances whose load characteristics are such that they operate together to give an improved load factor, the electric resistance heating system caused a reduction in residential load factor.

## PERSONAL . . . . .

A. M. MacCutcheon

## A. M. MacCutcheon to Receive the Lamme Medal for 1947

**Alexander Mardin MacCutcheon** (A '12, M '15, F '26) retired vice-president of the Reliance Electric and Engineering Company, Cleveland, Ohio, and a past president (1936–37) of the AIEE, has been awarded the 1947 AIEE Lamme Medal "For his distinguished accomplishments in the development of motors for industrial needs, notably in the steel industry." Mr. MacCutcheon was born at Stockport, N. Y., December 31, 1881, and after graduation from the State Normal College in 1901 taught mathematics and science in high schools until in 1904 he entered the electrical engineering course in Columbia University, from which he was graduated in 1908. He was employed by the Crocker Wheeler Company, Ampere, N. J., from 1909 to 1914, when he took charge of all new design work for the Reliance Electric and Engineering Company. He was appointed chief engi-

E. S. Lee | Victor Siegfried | J. L. Callahan | I. A. Terry | Richard McKay

neer in 1917, but in the same year entered the United States Navy and was a lieutenant at the time of his release from active service in 1919. He then returned to his former position and the following year was elected a director of the company. In 1923 he became vice-president in charge of engineering and in 1945 became senior vice-president, a position from which he retired in 1946, although he remained available to the company as a consultant. Mr. MacCutcheon was a director of the Institute 1928–32, and served on many AIEE committees, most recent being the John Fritz Medal board of awards (1936–40) and the committees on Institute policy (1937–40), constitution and by-laws (1939–40), and planning and co-ordination (1939–40). He also is a member of the Association of Iron and Steel Electrical Engineers, in which he has served on various committees. Mr. MacCutcheon is recognized as an authority on the subject of motor applications for steel mill auxiliaries, and in the National Electric Manufacturers Association was one of the leaders in bringing about the standardization of uniform motor mounting dimensions. He also has been active in the development of the Cleveland Technical Societies Council, and has been AIEE representative on the United States National Committee of the International Electrotechnical Commission and the electrical standards committee of the American Standards Association.

## E. S. Lee Nominated for Institute President

**Everett Samuel Lee** (A '20, M '28, F '30) engineer, general engineering and consulting laboratory, General Electric Company, Schenectady, N. Y., has been nominated for the presidency of the AIEE for the 1948–49 term. He was born in Chicago, Ill., November 19, 1891, and received the degrees of bachelor of science in electrical engineering from the University of Illinois in 1913 and of master of science in electrical engineering from Union College in 1915. From 1913 to 1916 he was an instructor in electrical engineering at Union College and a laboratory assistant at General Electric Company, Schenectady. He was a mechanical expert for the Locomotive Stoker Company in Pittsburgh, Pa., in 1916–17, and during World War I served as a first lieutenant. Returning to General Electric in 1919, he was associated with the general engineering laboratory, becoming division engineer of the general instrument division. In 1923 he became division engineer of the insulation division. Mr. Lee was advanced to the position of assistant engineer of the laboratory in 1928, and in 1931 became engineer. He assumed his present title in 1945. Mr. Lee has served as vice-president representing District 1 (1940–42) and has been a director of the Institute (1933–37) and chairman of the Schenectady Section (1928–29). He has served on the following national committees: executive (1933–37), headquarters (1936–37), Sections (1929–34), meetings and papers (1927–30; now technical program committee), membership (1933–38, chairman 1936–37), and transfers (1934–36, 1937–39, chairman 1937–39). He represented the Institute on the division of engineering and industrial research of the National Research Council (1936–39), and is at present serving on the planning and co-ordination committee, on the board of trustees of United Engineering Trustees, as a representative on Engineers' Council for Professional Development, and as a member of the AIEE committee on instruments and measurements on which he has served since 1928. Mr. Lee's record of service to the engineering profession also includes membership and active participation in the following organizations: American Standards Association, American Society of Mechanical Engineers, Institute of Radio Engineers, American Society for Engineering Education, New York State Society of Professional Engineers, National Society of Professional Engineers, American Society for Testing Materials, and the Newcomen Society of England—North American Branch.

## Vice-Presidential Nominees Are Siegfried, Callahan, Terry, Pingree, and McKay

**Victor Siegfried** (A '32, M '38) chief research engineer, electrical cable works, American Steel and Wire Company Worcester, Mass., has been nominated to serve the Institute as vice-president representing the North Eastern District (number 1). He was born at Seattle, Wash., December 13, 1909, and was graduated from Leland Stanford Junior University in 1930 with a degree of bachelor of arts and in 1932 received an engineering degree. Subsequently he was a graduate student at Harvard University, and in 1933 became an instructor in electrical engineering at Worcester Polytechnic Institute, Worcester, Mass., and assistant professor in 1937. During the summers of 1937 and 1940, Mr. Siegfried was employed in the high-voltage engineering laboratory of the General Electric Company in Pittsfield, Mass., and in 1944 he joined the American Steel and Wire Company in his present position. For several years Mr. Siegfried was counsellor of the AIEE Student Branch at Worcester Polytechnic Institute, and he served as chairman of the Worcester Section 1937–38. Since 1943 he has been secretary-treasurer of the North Eastern District, and his AIEE committee activities include service on the Sections (1947–48), membership (1940–43), and mining and metal industry (1946–48). He has written several AIEE papers and discussions on electric machinery and controls, and on electric cables. His society memberships include the American Society for Testing Materials, the American Chemical Society, the National Research Council Conference on Electrical Insulation, American Society for Engineering Education, American Association for the Advancement of Science, and Sigma Xi.

**John L. Callahan** (M '35) assistant to director, radio systems research laboratory, Radio Corporation of America, RCA laboratories division, and assistant to vice-president in charge of research and development, RCA Communications, Inc., New York, N. Y., has been nominated to serve the Institute as vice-president representing the New York City District (number 3). Mr. Callahan was born on December 9, 1898, at Minneapolis, Minn., receiving his early engineering training in Army electrical and signal schools, and later taking a postgraduate course in radio engineering at Sorbonne University. In 1920 he became associated with the engineering department of the Radio Corporation of America in com-

G. N. Pingree | C. W. Fick | F. O. McMillan | M. D. Hooven | W. I. Slichter

munication research and in 1930 was made research section head in charge of the terminal facilities research laboratory. Since 1945 he has been assistant to the vice-president in charge of research and development, RCA Communications, Inc., and assistant to director of radio systems research, Radio Corporation of America, RCA laboratories division. Mr. Callahan is a fellow, past president, and currently a director of the Radio Club of America, and a senior member of the Institute of Radio Engineers. He is currently chairman of the AIEE communications committee, on which he has served since 1941, and is secretary of District 3, a position which he has filled since 1946 after serving previously 1943–44. He was chairman of the Section in 1945–46.

**Ira A. Terry** (A'27, F'37) assistant manager of engineering, fractional horsepower motor divisions, General Electric Company, Fort Wayne, Ind., has been nominated to serve the Institute as vice-president representing the Great Lakes District (number 5). A native of Ogden, Utah, where he was born October 31, 1903, Mr. Terry was graduated from the University of Utah with the degree of bachelor of science in electrical engineering in 1925, after already having served three years as principal of a grade school in Darby, Idaho. He received the degree of master of science from Union College in 1929 while in the employ of the General Electric Company, Schenectady, which he had entered in 1925 as a student engineer. In 1930 he was placed in charge of research developmental work of the a-c engineering department, and three years later became assistant engineer in the motor and generator engineering department. Mr. Terry was appointed to the general staff of the works manager in 1940, and to the position of general assistant to the vice-president in charge of apparatus design engineering in 1942. Since 1946 he has been at Fort Wayne, first as works engineer and since 1947 with his present title. Mr. Terry was a member of the AIEE board of examiners from 1944 to 1946, and is a member of the American Society of Mechanical Engineers, the American Society for Quality Control and of other organizations. He is the author of several papers.

**George Nathan Pingree** (A'34, M'41) transformer specialist, General Electric Company, Dallas, Tex., has been nominated to serve the Institute as vice-president representing the Southwest District (number 7). Born on April 28, 1898, at New London, N. H., he attended Colby Academy at New London and received the degree of bachelor of science in electrical engineering from the University of New Hampshire in 1920, after having served in the United States Naval Reserve during World War I. He entered the employ of the General Electric Company at Schenectady, N. Y., following graduation from college, and after completion of the test course spent some time in laboratory work on vacuum tube application. In 1922 he was transferred to Pittsfield, Mass., where he spent several months on transformer design before entering the transformer commercial department. In 1926 he became transformer specialist in the southwestern district of the company with headquarters in Dallas, in which capacity he has had contact with many phases of transmission, distribution, and circuit protection problems in the Southwest. A registered professional engineer and active in the affairs of the Texas Society of Professional Engineers, he has held numerous offices in the AIEE North Texas Section, of which he was chairman in 1941.

**Richard McKay** (M'44) assistant general manager, The Washington Water Power Company, Spokane, Wash., has been nominated to serve the Institute as vice-president representing the North West District (number 9). He also was a member of AIEE from 1922 to 1932. Mr. McKay was born July 21, 1895, at Almira, Wash., and received his education at Whitman College and at Columbia University. During World War I he served as a first lieutenant in the United States Army. Since the beginning of his career in 1921, he has been identified with The Washington Water Power Company, starting as draftsman and becoming electrical engineer in 1926, district manager in the Coeur d'Alene office in 1932, manager of the rate department in the following year, and assistant general manager in 1942 with general charge of operations and engineering including generation, transmission, distribution, and complete division operation. He has been active in local civic and Section affairs, and is the chairman of the 1948 Pacific general meeting committee.

## Fick, Hooven, and McMillan Nominated for Directorships

**Clarence William Fick** (A'16, M'25, F'39) district manager, apparatus department, General Electric Company, Cleveland, Ohio, has been nominated to serve on the AIEE board of directors. He was born on September 30, 1890, in St. Joseph, Mo., and was graduated in 1912 with a bachelor of science degree in electrical engineering from the University of Illinois. Early in the following year he entered the employ of the General Electric Company in Schenectady, N. Y., as a student engineer. After periods as assistant general foreman of the testing department and of industrial application engineering, he was transferred to Portland, Oreg., as district engineer. In 1931 he was made district engineer of the east central district with headquarters in Cleveland, Ohio, and in 1945 became manager of that district. Mr. Fick has served as member and chairman of many local and some national committees in Schenectady, Portland, and Cleveland. He became chairman of the Cleveland Section in 1935; other AIEE activities include membership on the committee on applications to iron and steel production (1936–37), board of examiners (1943–45), and committee on transfers, on which he has served since 1946. He is a member of several Cleveland organizations.

**Morris Daniel Hooven** (A'24, M'30, F'44) electrical engineer, electric engineering department, Public Service Electric and Gas Company, Newark, N. J., has been nominated to serve on the AIEE board of directors. Born May 30, 1897, in Weatherly, Pa., Mr. Hooven was graduated from Bucknell University in 1920. Prior to that time he had been a machine hand at Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., furnace chemist at Carnegie Steel Company, Braddock, Pa., and a private in the Signal Corps, United States Army. In 1920 he returned to the

Westinghouse Company and a year later became manager of the radio department of the Robbins Electric Company, Pittsburgh, Pa. He entered the employ of Public Service Electric Company, Newark, N. J., in 1922 as one of the group engaged in the planning and design of the 132-kv system. He handled miscellaneous assignments in transmission and substation work, receiving the title of assistant transmission and substation engineer in 1939. Since 1942 he has been electrical engineer, electric engineering department. Mr. Hooven has held many New York Section offices, including that of chairman in 1944. In 1945–47 he was chairman of the AIEE technical program committee and of the committee on award of Institute prizes, and also during the same period chairman of the technical activities subcommittee of the planning and coordination committee. In the Edison Electric Institute he has held various committee chairmanships since 1924, including that of chairman of the inductive co-ordination committee in 1930 and chairman of the engineering subcommittee on depreciation in 1940. He is an associate member of the Institute of Radio Engineers, a member of the National Society of Professional Engineers, and a past president of the Montclair Society of Engineers.

**Fred Orville McMillan** (A '14, M '26, F '32) professor and head of the electrical engineering department, Oregon State College, Corvallis, has been nominated to serve on the AIEE board of directors. Professor McMillan was born May 12 1890, in Albia, Iowa, and holds the degrees of bachelor of science in electrical engineering (1912) from Oregon State College and master of science in electrical engineering (1919) from Union College, Schenectady, N. Y. He entered the testing department of the General Electric Company, Schenectady, N. Y., in 1912 and transferred to the engineering department in 1914 where he was engaged in design engineering for six years. In 1920 he was appointed to the electrical engineering faculty at Oregon State College as assistant professor, becoming associate professor in 1923, research professor in 1930, and professor of electrical engineering and head of the department in 1937. In addition to educational work he has served a number of utilities, industries, municipalities, and Federal agencies as a consultant. He was appointed electrical engineering specialist to assist the Chinese Government with problems in China during 1943 and 1944. Much of his research work has been in the field of high-voltage phenomena, including the grounded sphere-gap polarity effect and radio interference from high-voltage lines and associated equipment. This work has been reported in AIEE papers and other publications. He has served on the following AIEE committees: Student Branches (1930–36), education (1939–40), research (1934–41), electrophysics (1934–37), special committee to revise Section territories (1935), transfers (1936–42; chairman 1939), and research (1934–40). He was vice-president representing AIEE District 9 during 1934–36 and also was Oregon State College Branch student counsellor 1930–34 and 1942–43. His society affiliations include the American Association for the Advancement of Science, American Society for Engineering Education, Institute of Radio Engineers, Northwest Electric Light and Power Association, Professional Engineers of Oregon, and the Corvallis Engineers Club. He is also a member of Tau Beta Pi, Sigma Xi, Sigma Tau, Eta Kappa Nu, and Phi Kappa Phi.

## W. I. Slichter Renominated as Institute Treasurer

**Walter Irvine Slichter** (A '00, M '03, F '12) professor emeritus of electrical engineering, Columbia University, New York, N. Y., has been renominated to serve as AIEE treasurer, an office he has held since 1930. Born in St. Paul, Minn., Professor Slichter was graduated from Columbia University in 1896. After an interim of seven years with the General Electric Company, Schenectady, N. Y., he returned to Columbia University as professor and head of the department of electrical engineering. He has been professor emeritus since 1941. Professor Slichter has given many years of service to AIEE committee work and currently is a member of the Institute committees on the Edison Medal, Members-for-Life Fund, Standards, and applications of electricity to therapeutics.

**N. L. Towle** (A '20, M '24) professor and head of the electrical engineering department, The Cooper Union, New York, N. Y., has been appointed acting dean of the school of engineering. He has been a member of the faculty since his appointment as instructor in electrical engineering in 1920.

**M. B. Mallett** (M '36) transformer engineer, English Electric Company of Canada, Ltd., St. Catharines, Ontario, has been appointed chief engineer of the company. He was graduated from Rennsselaer Polytechnic Institute with the degree of electrical engineer in 1924, and received student test training with the General Electric Company until 1926. From 1926 to 1941 he was in the transformer engineering department of the General Electric Company, Pittsfield, Mass., specializing in high-voltage power transformer design. In 1941, he joined English Electric Company of Canada, Ltd., as transformer engineer, where his activities included the development of a basic type of shielded high-voltage power transformer design which has been described in two Institute papers. The holder of a number of patents on transformer design, he is a member of Sigma Xi and of the Professional Engineers Association of Ontario.

# OBITUARY

**Alexander Maxwell** (F '37) retired director of engineering of the Edison Electric Institute, New York, N. Y., died February 10, 1948. He was born in New York, May 13, 1878, and in 1894 became an assistant in the laboratory and testing department of the Westinghouse Electric and Manufacturing Company, Newark, N. J. The following year he became associated with the New York (N. Y.) Edison Company and predecessor electric lighting companies as assistant superintendent of operations in charge of the electrical and general laboratory and as engineer of distribution. Mr. Maxwell became an engineer for the National Electric Light Association, New York, in 1924 and continued with that organization until it was dissolved and succeeded by the Edison Electric Institute. He was made a director of engineering upon the formation of the latter in 1933, a position which included supervision of the organized activities of the electric-light and power-supply industry in the fields of engineering and allied managerial activities. He had retired in 1946. An AIEE member from 1903 to 1926, the activities in which Mr. Maxwell participated included service on the board of examiners from 1938 to 1946 (chairman in the last year), and as a member of the Standards committee (1940–46), the technical program committee (1940–42), and the committee on domestic and commercial applications (1940–43; chairman 1940–42). A recognized authority on standardization and formulation of codes affecting power supply and distribution, he rendered distinguished service as an active member of the electrical committee of the National Fire Protection Association, charged with the formulation of the National Electrical Code. In industry relations with other bodies similarly concerned he represented the viewpoint and interest of the utility industry. During World War I he served in the Corps of Engineers and in the field artillery, attaining the rank of lieutenant colonel.

**James H. McGraw** (A '01, member for life) honorary chairman, McGraw-Hill Publishing Company, Inc., New York, N. Y., died February 21, 1948. A native of Panama, N. Y., where he was born December 17, 1860, he was graduated from the State Normal School at Fredonia in 1884 as valedictorian of his class. He entered the publishing business in 1885 with the American Railway Publishing Company after short periods of teaching, starting his career with selling subscriptions and advertising for the *American Journal of Railway Appliances*, *Steam* (later rechristened *Power*), and *Street Railway Journal*, Mr. McGraw became vice-president of the publishing house at the age of 26. One of his fundamental beliefs was that the editors of business and technical journals should provide a vehicle for advancing

thought rather than merely reflecting current news and opinions. Following a merger in 1915, the McGraw Publishing Company became the McGraw-Hill Publishing Company, with nine publications. The McGraw-Hill Book Company had been formed 7 years earlier. In 1925, he established the James H. McGraw award for electrical men as an endowed award "to encourage constructive thinking for the advancement of the electrical industry." He was awarded the degree of doctor of commercial science by New York University in 1929, having previously received the Bok gold medal presented "for distinguished personal service to American commerce and industry through raising the standards of advertising." He was a member of the American Society of Mechanical Engineers, the Illuminating Engineering Society, and the National Electric Light Association (subsequently Edison Electric Institute), as well as many other societies and clubs not associated with the electrical industry.

**John F. Buckhold** (A '46) electrical engineer, Clark Controller Company, Cleveland, Ohio, died January 3, 1948. He was born September 12, 1904, at Cleveland, and was graduated from the Case School of Applied Science with a degree of bachelor of science in electrical engineering in 1933. From 1934 to 1937 he was engaged in the design of electric motors with the Ohio Electric Manufacturing Company, and then joined the Clark Controller Company as engineer charged with the supervision of design of electric control apparatus.

**Campbell MacMillan** (A '08, M '35, member for life) retired engineer of the General Electric Company, Schenectady, N. Y., died January 24, 1948. Born on February 3, 1875, in Glasgow, Scotland, he was graduated with honors in engineering from Glasgow University in 1894. His early experience included work in Lord Kelvin's laboratory in the development of instruments. Coming to the United States in 1902, he entered the test course of the General Electric Company and had a varied experience in the generator, transformer, and railway controller divisions. Two years later he returned to Scotland on a leave of absence to lecture at Glasgow University, and resumed his career with the General Electric Company the following year in the railway motor department, transferring to the a-c engineering department in 1907. In 1908 he returned to Scotland for two years as managing director of Electric Control, Ltd., after which he again returned to Schenectady in the newly formed induction motor department. His many special interests included the theory of multiple armature windings, and the behavior of magnetic materials. When he retired in 1941, he had been granted 37 United States patents for his varied inventions. Becoming an American citizen in 1916, he thereafter took an active part in civic affairs. He was a member of the Institution of Electrical Engineers (London) and of the Institution of Engineers and Shipbuilders of Scotland.

# MEMBERSHIP . .

## Recommended for Transfer

The board of examiners, at its meeting of February 19, 1948, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the secretary of the Institute.

### To Grade of Fellow

Aydelott, J. C., section head, elec. design, transportation motor engg. div., General Electric Co., Erie, Pa.

Collins, H. W., supt. elec. system, Detroit Edison Co., Detroit, Mich.

Ghen, M. W., supt. of operations, downtown div., Duquesne Light Co., Pittsburgh, Pa.

Kerr, W. E., vice pres. & treas., Pennsylvania Transformer Co., Pittsburgh, Pa.

Knutz, W. H., special engr., Northern Indiana Public Service Co., Hammond, Ind.

Louis, H. C. E., supt. electric test, Consolidated Gas Elec. Lt. & Pr. Co. of Baltimore, Md.

Marsh, H. H., Jr., genl. supt. substations & shops, Duquesne Light Co., Pittsburgh, Pa.

Morecock, E. M., supervisor, elec. dept., Rochester Institute of Technology, Rochester, N. Y.

Pumphrey, F. H., head prof. of elec. engg., University of Florida, Gainesville, Fla.

Salton, H. D., chief design engr., Pennsylvania Transformer Co., Canonsburg, Pa.

Steinberg, M. J., div. engr., Consolidated Edison Co. of N. Y., Inc., New York, N. Y.

11 to grade of Fellow

### To Grade of Member

Baldwin, M. J., design engr., General Elec. Co., Erie, Pa.

Bonney, R. H., supervising engr., Caterpillar Tractor Co., Peoria, Ill.

Cruickshank, J. E., radio engr., Watson Labs., Red Bank, N. J.

Ellicock, A. B., elec. designing engr., James H. Kearney Corp., St. Louis, Mo.

Fogg, L. E., elec. engr., Kennecott Wire & Cable Co., Phillipsdale, R. I.

Goldsmith, Sidney, chief operating engr., The Cincinnati Gas & Elec. Co., Cincinnati, Ohio

Gossman, L. Z., design engr., General Elec. Co., Decatur, Ind.

Irish, F. M., asst. supt. of power, Central Arizona Lt. & Pr. Co., Phoenix, Ariz.

Johnson, W. J., district plant engr. Illinois Bell Tel. Co., Chicago, Ill.

Jordan, R. B., section-chief, physical & electrical lab., Western Electric Co. Inc., Kearny, N. J.

Lamborn, R., design engr., General Elec. Co., Erie, Pa.

Miller, J. F., elec. engr., General Elec. Co., Los Angeles, Calif.

Miller, W. E., asst. prof., elec. engg. dept., Univ. of Illinois, Urbana, Ill.

Nevitt, C. J., supt. of elec. transmission & distribution, San Diego Gas & Elec. Co., San Diego, Calif.

Newburgh, H., asst. prof., Pennsylvania State College, State College, Pa.

Peterson, C., physicist, National Bureau of Standards, Washington, D. C.

Randolph, H. J., elec. engr., J. J. Costello Co., Boston, Mass.

Reid, J. G., Jr., chief, electronic instrumentation lab., National Bureau of Standards, Washington, D. C.

Rheaume, R. H., project engr. on development, Machlett Labs., Inc., Springdale, Conn.

Schahfer, R. M., mech. & elec. engr., Northern Indiana Public Serv. Co., Hammond, Ind.

Sinclair, W. A., engr., The Detroit Edison Co., Detroit, Mich.

Steinmetz, R. B., mgr., Marion Mill Sales, Anaconda Wire & Cable Co., Marion, Ind.

Stokely, M. M., elec. engr., J. E. Sirrine Co., Greenville, S. C.

Suhr, F. W., design engr., group leader, General Elec. Co., Ft. Wayne, Ind.

Sylvester, J. D., asst. engr., Canadian National Railways, Montreal, Quebec, Can.

25 to grade of Member

## Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Any member objecting to the election of any of these candidates should so inform the secretary before April 21, 1948, or June 21, 1948, if the applicant resides outside of the United States, Canada, or Mexico.

### To Grade of Member

Ahmad, Z. U., Thomason College of Engg., Roorkee, UP, India

Atkins, J. L., Brown Corp., LaTuque, Quebec, Canada

Barnard, B. H., State School of Science, Wahpeton, N. D.

Clark, F. L., British Columbia Elec. Co., Vancouver, British Columbia, Canada

Crabb, V. L., Ohio Brass Co., Barberton, Ohio

Dobbs, C. L., Chicago Vocational School, Chicago, Ill.

Ellard, G. E., Boston Elevated Railway, Boston, Mass.

Ernst, C. C., California Elec. Power Co., Riverside, Calif.

Fuller, D. W., Benjamin Elec. Mfg. Co., Chicago, Ill.

Gavriel, S. N., Mass. Inst. of Tech., Cambridge, Mass.

Goodale, W. G., New England Power Co., Lawrence, Mass.

Griffith, L. M., Bunker Hill & Sullivan M. & C. Co., Kellogg, Idaho

Harrision, R. L., Hartman Elec. Mfg. Co., Mansfield, Ohio

Hemmes, R. T., General Elec. Co., Pittsfield, Mass.

Henderson, R. B., Manhattan College, New York, N. Y.

Henry, H. M., Kansas City Power & Light Co., Kansas City, Mo.

Hinder, G. W., U. S. Navy, Washington, D. C.

Hunter, A. M., American Steel & Wire Co., Waukegan, Ill.

Hussain, S. S., Govt. of West Punjab, Lahore, Pakistan

Johanson, J. E., Union Elec. Co., St. Louis, Mo.

Jorritsma, W. P., Royal Dutch Airlines, Schiphol Airport, Amsterdam, Holland

Kendall, G. A., W. C. Gilman & Co., New York, N. Y.

Kimball, D. G., General Elec. Co., Bridgeport, Conn.

Langlois, H. M., Dept. of Water & Power, Los Angeles, Calif.

Ludington, F. C., Allis-Chalmers Mfg. Co., Milwaukee, Wis.

MacRae, A. S., Dominion Govt. of Canada, Ottawa, Ontario, Canada

Meagher, J. F., Elizabethton Elec. System, Elizabethton, Tenn.

Mitacek, J., Skelly Oil Co., Pawhuska, Okla.

Moore, A. O., Greenwood County Elec. Power, Greenwood, S. C.

Mosher, R. F., General Elec. Co., Pittsfield, Mass.

Mullenbach, C. F., Mullenbach Elec. Mfg. Co., Los Angeles, Calif.

Neman, S., Lt. Cmdr., Postgraduate School, Annapolis, Md.

Nickelsen, E. A., California Pacific Utilities Co., San Francisco, Calif.

Osburn, M. P., Elec. Power Comm. of Ontario, Toronto, Ontario, Canada

Phillips, G. D., General Elec. Co., Erie, Pa.

Pierce, J. R., Bell Tel. Labs., Inc., New York, N. Y.

Pierson, G. L., The Ohio Public Service Co., Elyria, Ohio

Rowlatt, J. H., Consor (Canada), Ltd., Montreal, Quebec, Canada

Rowten, D. W., Westinghouse Elec. Corp., Cleveland, Ohio

Spencer, S. A., Edw. E. Ashley, New York, N. Y.

Stoakes, L. M., Allis-Chalmers Mfg. Co., Pittsburgh, Pa.

Straitman, G. T., Natl. Advisory Comm. for Aeronautics, Hampton, Va.

Treverton, W. R., Public Service Co. of Colorado, Denver, Colo.

Waehner, A. R., Line Material Co., Milwaukee, Wis.

Watter, A. H., The Shawinigan Water & Power Co., Shawinigan Falls, Quebec, Canada

White, A. P., Navy Dept., El Toro, Calif.

46 to grade of Member

### To Grade of Associate

**United States, Canada, Alaska, and Puerto Rico**

1. North Eastern

Abbott, R. E., General Elec. Co., Schenectady, N. Y.

Achramowicz, M. J., Joseph E. Murphy Co., Worcester, Mass.

Ambush, C., Stromberg-Carlson Co., Rochester, N. Y.

Amish, K. W., Rochester Gas & Elec. Corp., Rochester N. Y.

Anderson, C. W., New England Tel. & Tel., Lexington, Mass.
Antalis, S. J., General Elec. Co., Pittsfield, Mass.
Armington, J. C., Tufts College, Medford, Mass.
Arthur, G. M., Fitchburg Engg. Corp., Fitchburg, Mass.
Baldwin, A. L., Argraves & Mort, New Haven, Conn.
Bang, B. A., General Elec. Co., Schenectady, N. Y.
Barrett, J. J., New England Tel. & Tel. Co., Boston, Mass.
Barton, S. C., General Elec. Co., Schenectady, N. Y.
Begley, R. E., The Oakes Companies, Holyoke, Mass.
Behnken, H. A., The Torrington Co., Torrington, Conn.
Bell, R. A., General Elec. Co., Schenectady, N. Y.
Bennett, B. F., General Elec. Co., Schenectady, N. Y.
Bennett, N. F., Stromberg-Carlson Co., Rochester, N. Y.
Berry, R. E., General Elec. Co., Schenectady, N. Y.
Blair, N. M., Bristol Co., Waterbury, Conn.
Bowen, F. J., Jr., General Elec. Co., Schenectady, N. Y.
Bowles, J. A., General Elec. Co., Schenectady, N. Y.
Bristor, A. F., Jr., General Elec. Co., Schenectady, N. Y.
Brophy, J. E., Jr., Westinghouse Elec. Corp., Buffalo, N. Y.
Brown, P. G., General Elec. Co., Schenectady, N. Y.
Buerger, E. J., General Elec. Co., Schenectady, N. Y.
Burak, F. J., Reed-Prentice Corp., Worcester, Mass.
Burkart, H. H., General Elec. Co., Schenectady, N. Y.
Burnett, J. W., General Elec. Co., Pittsfield, Mass.
Carroccio, M. J., General Elec. Co., Schenectady, N. Y.
Chagnot, H. F., The Gamewell Co., Newton Upper Falls, Mass.
Chapman, C. E., General Elec. Co., Schenectady, N. Y.
Christensen, H. W., General Elec. Co., Schenectady, N. Y.
Coles, W. J., General Elec. Co., Schenectady, N. Y.
Crumly, C. B., General Elec. Co., Schenectady, N. Y.
Davenport, R. B., General Elec. Co., Schenectady, N. Y.
Dix, C. W., General Elec. Co., Syracuse, N. Y.
Dobbins, F. K., Jr., General Elec. Co., Schenectady, N. Y.
Easley, J. H., General Elec. Co., Pittsfield, Mass.
Elder, J. C., General Elec. Co., Schenectady, N. Y.
Ellis, C. L., General Elec. Co., Pittsfield, Mass.
Falk, L. M., Submarine Signal Co., Boston, Mass.
Fantini, A. J., General Elec. Co., Schenectady, N. Y.
Feltner, J. B., General Elec. Co., Schenectady, N. Y.
Fontana, J. A., Manning, Maxwell & Moore, Bridgeport, Conn.
French, H. B., General Elec. Co., Schenectady, N. Y.
Fronko, E. G., General Elec. Co., Lynn, Mass.
Fryncko, P., Black Rock Mfg. Co., Bridgeport, Conn.
Garbe, H. F., General Elec. Co., Pittsfield, Mass.
Gardner, J. B., The Kerite Co., Seymour, Conn.
George, R. E., Alvin S. Mancib Co., West Somerville, Mass.
Gesert, R. A., General Elec. Co., Schenectady, N. Y.
Giannattasio, M., Stone & Webster Engg. Corp., Boston, Mass.
Gibbs, D. F., General Elec. Co., Schenectady, N. Y.
Gleixner, H., General Elec. Co., Schenectady, N. Y.
Goettman, A. T., U. S. Rubber Co., Woonsocket, R. I.
Gordon, D. B. (Mrs.), Cornell Univ., Ithaca, N. Y.
Gore, S. A., General Elec. Co., Schenectady, N. Y.
Grammer, R. A., Jr., Eastman Kodak Co., Rochester, N. Y.
Graves, W. M., III, General Elec. Co., Schenectady, N. Y.
Greene, R. L., Clarkson College of Tech., Potsdam, N. Y.
Grim, W. M., Jr., Mass. Inst. of Tech., Cambridge, Mass.
Grimala, W. J., Jr., Rockwood Sprinkler Co., Worcester, Mass.
Hale, W. O., Westinghouse Elec. Corp., Boston, Mass.
Hand, T. R., General Elec. Co., Schenectady, N. Y.
Hanson, E. M., General Elec. Co., Schenectady, N. Y.
Harkey, M. L., Jr., General Elec. Co., Pittsfield, Mass.
Hartwig, W. H., Cornell Univ., Ithaca, N. Y.
Helder, G., General Elec. Co., Schenectady, N. Y.
Henson, F. H., Stromberg-Carlson Co., Rochester, N. Y.
Hierl, J. J., General Elec. Co., Schenectady, N. Y.
Hinton, C. B., General Elec. Co., Schenectady, N. Y.
Holland, M., General Elec. Co., Schenectady, N. Y.
Hotaling, W. E., Intl. Business Machines Corp., Poughkeepsie, N. Y.
Hull, H. P., Jr., Southern New England Tel. Co., New Haven, Conn.
Hulsizer, J. C., General Elec. Co., Lynn, Mass.
Ingemanson, C. R., General Elec. Co., Pittsfield, Mass.
Jackson, W. E., Tufts College, Medford, Mass.
Jameson, E. E., Jr., General Elec. Co., Schenectady, N. Y.
Johnson, L. W., General Elec. Co., Schenectady, N. Y.
Kastner, J. M., General Elec. Co., Schenectady, N. Y.
King, R. M., General Elec. Co., Lynn, Mass.
Knauf, C. L., Jr., General Elec. Co., Schenectady, N. Y.
Knowles, R. W., General Elec. Co., Pittsfield, Mass.
Kroha, B. K., 175 Lawrence St., New Haven, Conn.
Krings, F. C., General Elec. Co., Schenectady, N. Y.
Krogen, E. J., General Elec. Co., Schenectady, N. Y.
Laass, R. G., Argentine Consulate, Boston, Mass.
La Plante, R. J., General Elec. Co., Lynn, Mass.
Larko, R. C., Service Engg. Co., Somersworth, N. H.
Lawrence, P. B., General Elec. Co., Pittsfield, Mass.
Lennig, M., General Elec. Co., Schenectady, N. Y.
Leoni, L. C., Brown Univ., Providence, R. I.
Levy, H. F., General Elec. Co., Schenectady, N. Y.
Lewis, D. G., Jr., General Elec. Co., Lynn, Mass.
Lingo, L. E., General Elec. Co., Schenectady, N. Y.
Liu, L., Cornell Univ., Ithaca, N. Y.
Loeb, L. M., The General Elec. Co., Schenectady, N. Y.
Loscocco, F. A., Allis-Chalmers, Boston, Mass.
Lovallo, D., General Elec. Co., Schenectady, N. Y.
Madison, T. C., General Elec. Co., Lynn, Mass.
Mallery, C. G., General Elec. Co., Schenectady, N. Y.
Marcinkiewicz, E., Boston Edison Co., Boston, Mass.
Marino, J. P., Marino Jewelry Mfg. Co., Inc., Pawtucket, R. I.
Mark, R. C., Telechron Inc., Ashland, Mass.
Marsh, W. D., General Elec. Co., Schenectady, N. Y.
McDonnell, F. A., General Elec. Co., Bridgeport, Conn.
Meacham, J. W., Hartford Elec. Light Co., Hartford, Conn.
Meranus, D. J., General Elec. Co., Schenectady, N. Y.
Mogavero, A. A., 126 Main St., Cooperstown, N. Y.
Mooers, H. T., Zator Co., Cambridge, Mass.
Mott, J. S., General Elec. Co., Schenectady, N. Y.
Nayman, H., General Elec. Co., Schenectady, N. Y.
Nord, H. H., Colonial Radio Corp., Buffalo, N. Y.
Perlman, S. E., 121 Perry Ave., Lawrence, Mass.
Pilimore, G. A., General Elec. Co., Schenectady, N. Y.
Pisano, J. P., Carrier Corp., Syracuse, N. Y.
Plehn, G., General Elec. Co., Syracuse, N. Y.
Praeger, W. C., Rochester Gas & Elec. Co., Rochester, N. Y.
Prutton, R. V., General Elec. Co., Schenectady, N. Y.
Puliafico, C. A., Stone & Webster Engg. Corp., Boston, Mass.
Quint, S. F., 58 Supple Road, Roxbury, Mass.
Ralls, J. W., General Elec. Co., Schenectady, N. Y.
Ramsey, W., General Elec. Co., Schenectady, N. Y.
Raney, A. K., General Elec. Co., Pittsfield, Mass.
Reals, C. H., General Elec. Co., Schenectady, N. Y.
Redfern, A. H., Electro Metallurgical Co., Niagara Falls, N. Y.
Rickley, A. L., Doble Engg. Co., Belmont, Mass.
Roby, J. G., General Elec. Co., Schenectady, N. Y.
Roelofs, S. R., General Elec. Co., Schenectady, N. Y.
Roenquist, H. T., General Elec. Co., Pittsfield, Mass.
Samson, D. R., General Elec. Co., Schenectady, N. Y.
Samson, R. H., General Elec. Co., Lynn, Mass.
Serrurier, T. A., General Elec. Co., Pittsfield, Mass.
Shields, W. B., General Elec. Co., Schenectady, N. Y.
Silverman, H. M., 33 Crawford St., Roxbury, Mass.
Spalding, J. D., Tufts College, Medford, Mass.
Standord, C. H., New York Tel. Co., Albany, N. Y.
Stavely, E. B., Jr., General Elec. Co., Schenectady, N. Y.
Stowell, F. B., Stromberg Carlson Co., Rochester, N. Y.
Thibeault, H. A., Central Maine Power Co., Augusta, Me.
Tice, J. B., General Elec. Co., Schenectady, N. Y.
Torchia, H. A., General Elec. Co., Pittsfield, Mass.
Trull, S. G., Jr., Central Hudson Gas & Elec. Corp., Kingston, N. Y.
Tull, I. N., Jr., General Elec. Co., Bridgeport, Conn.
Vallandingham, C. D., Eastman Kodak Co., Rochester, N. Y.
Van Bloom, A. M., General Elec. Co., Schenectady, N. Y.
Vasel, A. W., Alden Products Co., Brockton, Mass.
Verheyden, V. E., General Elec. Co., Schenectady, N. Y.
Wallnau, D. W., Dictaphone Corp., Bridgeport, Conn.
Wampler, D. D., General Elec. Co., Schenectady, N. Y.
Weiner, S. B., Stromberg-Carlson Co., Rochester, N. Y.
Whelan, R. J., General Elec. Co., Schenectady, N. Y.
Williams, W. A., Heald Machine Co., Worcester, Mass.
Wilson, K. E., General Elec. Co., Schenectady, N. Y.
Woll, A., Harvard Graduate School of Engg., Cambridge, Mass.
Wood, M. E., N. Y. State Inst. of Applied Arts & Sciences, Binghamton, N. Y.
Workman, W. S., General Elec. Co., Schenectady, N. Y.
Wottlin, W. O., General Elec. Co., Schenectady, N. Y.
Zimmer, S. J., General Elec. Co., Schenectady, N. Y.

2. MIDDLE EASTERN

Adams, D., Wheeling Steel Corp., Benwood, W. Va.
Anderson, H. W., Goodyear Tire Rubber Co., Akron, Ohio
Arlt, R. G., Robbins & Myers, Inc., Springfield, Ohio
Artley, J. L., Ideal Elec. & Mfg. Co., Mansfield, Ohio
Ashton, T., Lincoln Elec. Co., Cleveland, Ohio
Auerbach, I. L., Eckert-Mauchly Computer Corp., Philadelphia, Pa.
Bailey, J. B., Jr., Cleveland Elec. Illuminating Co., Cleveland, Ohio
Barber, L. W., Western Elec., Allentown, Pa.
Bayne, E. L., Natl. Tube Co., Amherst, Ohio
Beaumont, W. H., Bell Tel. Co., Philadelphia, Pa.
Belsky, R. L., General Elec. Co., Philadelphia, Pa.
Bishop, W. W., General Elec. Co., Erie, Pa.
Black, W. S., III, American Tel. &Tel. Co., Philadelphia, Pa.
Bondesen, S. O., The Ohio Bell Tel. Co., Cleveland, Ohio
Bragdon, M. H., Naval Ordnance Lab., White Oak, Md.
Braun, W. E., Kingston-Conley Elec. Co., Cambridge, Ohio
Bright, R. L., Carnegie Inst. of Tech., Pittsburgh, Pa.
Broad, D. M., National Portland Cement Co., Bethlehem, Pa.
Brogan, J. L., Philco Corp., Philadelphia, Pa.
Brush, E. F., Central Ohio Light & Power, Findlay, Ohio
Buess, K. B., Cleveland Elec. Illuminating Co., Cleveland, Ohio
Burnside, D. F., Westinghouse Elec. Corp., Baltimore, Md.
Busch, H. F., 1126 Fairview Ave., Wyomissing, Pa.
Campbell, W. J., Leeds & Northrup, Philadelphia, Pa.
Carlson, C. V., Ohio Bell Tel. Co., Cleveland, Ohio
Clawson, R. E., The Dayton Power & Light Co., Dayton, Ohio
Clemson, J. R., Westinghouse Elec. Co., Pittsburgh, Pa.
Clover, F. W., Allis-Chalmers Mfg. Co., Pittsburgh, Pa.
Cockerham, F. E., John Paul Jones, Cary & Millar, Cleveland, Ohio
Coleman, R. S., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Conant, E. M., Westinghouse Elec. Co., E. Pittsburgh, Pa.
Davies, W. R., Jr., Westinghouse Elec. Corp., Cleveland, Ohio
Davis, F. W., Naval Ordnance Lab., Washington, D. C.
Davis, R. W., Jr., Brown Instrument, Philadelphia, Pa.
DeBorde, H. D., Baldwin Locomotive Works, Eddystone, Pa.
De Walt, R. D., Ohio Edison Co., Youngstown, Ohio
DeYoung, D. R., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Dimasi, L. A., Penn Technical Inst., Pittsburgh, Pa.
Dodds, J. A., Jr., Carnegie-Illinois Steel Corp., Duquesne, Pa.
Drews, D. W., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Dunham, R. W., General Elec. Co., Philadelphia, Pa.
Dwyer, D. P., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Dyner, B. L., James G. Biddle Co., Philadelphia, Pa.
Ellis, W. A., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Engle, R. G., Bell Tel. Co. of Pennsylvania, Pittsburgh, Pa.
Ericson, E. A., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Evans, R. K., The Greenville Elec. Light & Power Co., Greenville, Ohio
Eynon, J., Leeds & Northrup Co., Philadelphia, Pa.
Fallon, L. J., Philco Corp., Philadelphia, Pa.
Finch, W. H., Jr., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Fischer, J. W., Dayton Power & Light Co., Dayton, Ohio
Fox, A. M., Pennsylvania Transformer Co., Canonsburg, Pa.
Franz, J. P., Jr., Carnegie Inst. of Tech., Pittsburgh, Pa.
Freyer, E. (Miss), Philco Corp., Philadelphia, Pa.
Fritz, C. H., Shallcross Mfg. Co., Collingdale, Pa.
Garfinkel, A. R., H. L. Yoh Co., Philadelphia, Pa.
Gilkey, J. M., Dayton Power & Light Co., Dayton, Ohio
Giza, T. J., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Glatz, C. E., Allis-Chalmers Mfg. Co., Pittsburgh, Pa.
Goodill, J. J., Naval Research Lab., Washington, D. C.
Graff, W. S., Roberts & Mander Corp., Hatboro, Pa.
Graham, T. B., Allis-Chalmers Mfg. Co., Pittsburgh, Pa.
Graw, W. K., II, Carbide & Carbon Chem. Co., Charleston, W. Va.
Greaney, G. J., Jr., Elliott Co., Jeannette, Pa.
Greer, T. M., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Gunsett, J. K., Trumbull Elec. Mfg. Co., Norwood, Ohio
Haldeman, J. S., American Tel. & Tel. Co., Doylestown, Pa.
Ham, E. B., Philadelphia Elec. Co., Philadelphia, Pa.
Hammond, R. C., General Elec. Co., Philadelphia, Pa.
Hanger, R. T., United Engrs. & Constructors, Inc., Philadelphia, Pa.
Hatch, R. S., Westinghouse Elec. Co., E. Pittsburgh, Pa.
Havener, R. E., Mines Safety Appliances Co., Pittsburgh, Pa.
Heasley, J. D., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Helldorfer, J. A., Jr., Consolidated Gas Elec. Light & Power Co. of Baltimore, Baltimore, Md.
Hickman, R. W., American Tel. & Tel. Co., Cleveland, Ohio
Hinckley, K., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Hines, J. W., Radio Station *WBVP*, Beaver Falls, Pa.
Hobbs, J. C., Carnegie Inst. of Tech., Pittsburgh, Pa.
Hoffman, D. W., Carnegie-Illinois Steel Corp., Dravosburg, Pa.
Hoffman, R. J., Univ. of Pittsburgh, Pittsburgh, Pa.
Holley, E. L., Westinghouse Elec. Corp., Sharon, Pa.
Hoopes, H. W., Westinghouse Elec., E. Pittsburgh, Pa.

Hoover, R. M., Ordnance Research Lab., State College, Pa.
Howard, D. R., Columbus & Southern Ohio Elec. Co., Columbus, Ohio
Hungerford, K. S., General Motors Corp., Dayton, Ohio
James, H. B., Westinghouse Elec. Corp., Lima, Ohio
James, L. A., Bell Tel. Co. of Pennsylvania, Philadelphia, Pa.
Jensen, W. J., Western Elec. Co., Inc., Washington, D. C.
Jira, V., Wheeling Steel Corp., Yorkville, Ohio
Johnstone, J. W., Jr., Day & Zimmermann, Inc., Philadelphia, Pa.
Jones, A. R., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Jones, D. H., Allis-Chalmers Mfg. Co., Pittsburgh, Pa.
Kalbop, A. M., General Elec. Co., Philadelphia, Pa.
Karle, F. J., Delco Prods., Dayton, Ohio
Kauffman, J. U., Jr., Elliott Co., Jeannette, Pa.
Kehman, A. E., Westinghouse Elec. Co., E. Pittsburgh, Pa.
Kemper, J. M., Natl. Advisory Comm. for Aeronautics, Cleveland, Ohio
Kitchens, R. T., General Elec. Co., Philadelphia, Pa.
Klingler, C. R., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Knipp, F. R., The Dayton Power & Light Co., Dayton, Ohio
Knisely, C. G., The Clark Controller Co., Cleveland, Ohio
Koenig, H. E., General Motors Corp., Dayton, Ohio
Krehbiel, J. D., Elec. Auto-Lite, Toledo, Ohio
Kropotich, E., Naval Ordnance Lab., Washington, D. C.
Kubulak, B. G., Allis-Chalmers Mfg. Co., Pittsburgh, Pa.
Lanzilotta, V. M., Day & Zimmermann, Inc., Philadelphia, Pa.
Lee, D. E., Baldwin Locomotive Wks., Eddystone, Pa.
Limatainen, T. A., Carnegie-Illinois Steel Corp., Duquesne, Pa.
Logan, T. J., General Elec. Co., Philadelphia, Pa.
Logue, R. H., Philadelphia Elec. Co., Philadelphia, Pa.
Lund, G. R., Naval Ordnance Lab., Washington, D. C.
Lundy, G. W. C., Carnegie-Illinois Steel Corp., Clairton, Pa.
Mahnke, N. O., Hotel Olmsted, Cleveland, Ohio
Manko, R. E., General Elec. Co., Erie, Pa.
Marshall, A., General Elec. Co., Philadelphia, Pa.
Maupin, J. T., Bell Tel. Labs., Inc., c/o Western Elec. Co., Baltimore, Md.
McClellan, T. C., Delaware Power & Light Co., Wilmington, Del.
McKinnon, J. P., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
McNabb, R. C. J., General Elec. Co., Nela Park, Cleveland, Ohio
McNeill, R. E., Henry Adams, Inc., Baltimore, Md.
Mederer, S. J., Westinghouse Corp., E. Pittsburgh, Pa.
Meese, K. N., General Elec. Co., Philadelphia, Pa.
Meng, F. R., Bell Tel. Co. of Pennsylvania, Philadelphia, Pa.
Meng, D. R., (Bell Tel. Co. of Penna.), 150 Park Ave., Ambler, Pa.
Milan, L. F., Jr., Sperry Gyroscope Co., Baltimore, Md.
Miller, R. H., General Elec. Co., Philadelphia, Pa.
Mitchell, R. O., Day & Zimmermann, Inc., Philadelphia, Pa.
Mojkowski, Z., Westinghouse Elec. Corp., Pittsburgh, Pa.
Monnier, H. E., Allis-Chalmers Mfg. Co., Pittsburgh, Pa.
Monroe, G. J., West Virginia Univ., Morgantown, W. Va.
Moore, P. F., Lincoln Elec. Co., Cleveland, Ohio
Moreland, H. M., Ohio Bell Tel. Co., Cleveland, Ohio
Mori, J. H., Brown, Brockmeyer Co., Dayton, Ohio
Morris, J. A., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Moynihan, J. D., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Murray, J. G., Lincoln Elec. Co., Cleveland, Ohio
Murray, T. W., Pennsylvania Water & Power Co., Holtwood, Pa.
Mykita, J., Mine Safety Appliances Co., Pittsburgh, Pa.
Naslund, H. W., General Elec. Co., Erie, Pa.
Neri, Z., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Neu, A. J., Peaco Prods., Cleveland, Ohio
Null, V. A., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Oakes, A. H., Ohio Bell Tel. Co., Akron, Ohio
Oberly, K. G., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Oldroyd, H. A., Jr., Appalachian Elec. Power Co., Charleston, W. Va.
Ossman, W. R., Cleveland Elec. Illuminating Co., Cleveland, Ohio
Paris, O. H., Carnegie Illinois Steel Corp., Homestead, Pa.
Paska, R. A., The Johns Hopkins Univ., Baltimore, Md.
Peterson, P. E., General Elec. Co., Erie, Pa.
Phillips, W. M., The Ohio Power Co., Canton, Ohio
Pickholtz, I., Carnegie-Illinois Steel Corp., Braddock, Pa.
Podhorez, P. E., General Elec. Co., Erie, Pa.
Pollack, A. S., Naval Gun Factory, Washington, D. C.
Powell, J. L., Ohio Power Co., Canton, Ohio
Pravda, M. F., General Elec. Co., Philadelphia, Pa.
Ramandanes, G. H., Pennsylvania Elec. Co., Erie, Pa.
Remer, B. R., U. S. Patent Office, Washington, D. C.
Reuther, J. F., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Rich, W. E., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Risser, R. H., Ohio Brass Co., Mansfield, Ohio
Roberts, M. S., Pittsburgh Plate Glass Co., Clarksburg, W. Va.
Rooi, J. D., Brown Instrument Co., Philadelphia, Pa.
Rothauge, C. H., The Johns Hopkins Univ., Baltimore, Md.
Sandberg, C. E., The Ohio Public Service Co., Ashland, Ohio
Sanders, O. F., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Scheib, A. W., West Penn Power Co., Charleroi, Pa.
Schubkegel, A., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Schrank, G. B., Delco Products Div., G.M.C., Dayton, Ohio
Schultz, H. E., General Elec. Co., Cleveland, Ohio
Semer, M., Turner Construction Co., Philadelphia, Pa.
Simpson, A. W., Jr., General Elec. Co., Philadelphia, Pa.
Sims, D. S., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Skoff, C. L., Pennsylvania Power & Light Co., Allentown, Pa.
Slomski, S. L., General Elec. Co., Nela Park, Cleveland, Ohio
Slutz, L. F., Westinghouse Elec. Corp., Baltimore, Md.
Smith, E. R., Ohio Public Service Co., Cleveland, Ohio
Sopp, T. E., Philadelphia General Hospital, Philadelphia, Pa.
Sponholtz, L. B., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Stephens, R. R., American Tel. & Tel. Co., Philadelphia, Pa.
Stetler, J. S., Pennsylvania Power & Light Co., Hazleton, Pa.
Stewart, M. L., Stewart, Jr., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Stokes, C. A. Locke Insulator Corp., Baltimore, Md.
Stout, H. G., Carnegie-Illinois Steel Corp., Pittsburgh, Pa.
Stringer, L. F., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Szweda, R. J., Day & Zimmermann, Inc., Philadelphia, Pa.
Taylor, H. J., Delaware Power & Light Co., Wilmington, Del.
Thomas, J. F., Jr., Firestone Tire & Rubber Co., Akron, Ohio
Trejbal, J., c/o Czechoslovak Military & Air Attache, Washington, D. C.
True, A. R., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Trynosky, P. R., Pennsylvania Power & Light Co., Mt. Carmel, Pa.
Vijayan, S., Westinghouse Elec. Corp., Pittsburgh, Pa.
Vincent, R. C., Ordnance Research Lab., State College, Pa.
Watters, C. V., Westinghouse Elec. Co., E. Pittsburgh, Pa.
Weinberg, I., Philco Corp., Philadelphia, Pa.
Weiner, L., 1224 Blue Hill Ave., Mattapan, Mass.
Weinhardt, R. A., Wharton Graduate School of Business & Govt. Admin., Philadelphia, Pa.
Whitacre, D. R., City of Cuyahoga Falls Light Dept., Cuyahoga Falls, Ohio
Wickes, W. A., Cleveland Elec. Illuminating Co., Cleveland, Ohio
Willett, R. F., United Engrs. & Constructors, Inc., Philadelphia, Pa.
Willey, J. E., Jr., Eastern Shore Public Service Co., Salisbury, Md.
Winters, C. G., Line Material Co., Zanesville, Ohio
Winters, E. B., Jr., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Wischnia, H. F., Pennsylvania State College, State College, Pa.
Wise, C. E., Catholic Univ., Washington, D. C.
Wolf, E., Canister Co., Inc., Phillipsburg, N. J.
Wolff, J. L., Jr., Carnegie Inst. of Tech., Pittsburgh, Pa.
Young, A. E., Natl. Advisory Comm. for Aeronautics, Cleveland, Ohio
Wright, J. A., Ajax Electrothermic Corp., Trenton, N. J.
Zeh, R. J., Sylvania Elec. Prods., Inc., Huntington, W. Va.

### 3. New York City

Aberer, J. C., Bell Tel. Labs., New York, N. Y.
Adler, M., 1106 College Avenue, New York, N. Y.
Akin, K. E., Federal Tel. & Radio Corp., Clifton, N. J.
Anderson, R. E. D., Bell Tel. Lab., New York, N. Y.
Anglin, J. F., Long Island Lighting Co., Mineola, N. Y.
Bagley, G. F., New Jersey Bell Tel. Co., Rutherford, N. J.
Balch, H. T., Bell Tel. Labs, Inc., Whippany, N. J.
Barth, J. E., Socony-Vacuum Oil Co., Inc., Brooklyn, N. Y.
Bellew, F. N., Rutgers Univ., New Brunswick, N. J.
Benson, P. A., N. J. Bell Tel. Co., Newark, N. J.
Berman, L. S., Airborne Instruments Lab., Inc., Mineola, N. Y.
Bifano, V. J., Board of Transportation, New York, N. Y.
Bogner, L., Newark College of Engg., Newark, N. J.
Bresler, A. D., War Department, U. S. Forces Austria, % P. M., New York, N. Y.
Buchbinder, M. M., Pratt Inst., New York, N. Y.
Bullock, R. N., Intl. Business Machines Corp., New York, N. Y.
Burns, L. J., Celanese Corp. of America, New York, N. Y.
Carroll, E. S., Dept. of Public Works, New Rochelle, N. Y.
Caveglia, J. H., Long Island Lighting Co., Mineola, N. Y.
Cerino, R., N. Y. Naval Shipyard, Brooklyn, N. Y.
Chaber, R. K., Acro Transformer & Mfg. Co., New York, N. Y.
Chase, H. A., Board of Transportation, New York, N. Y.
Chen, T., New York Univ., New York, N. Y.
Ciccio, J. A., Federal Tel. & Radio Corp., Clifton, N. J.
Colman, A., Consolidated Edison Co. of N. Y., New York, N. Y.
Costa, T. A., Emerson Radio Co., Inc., New York, N. Y.
Davis, E. W., Mutual Broadcasting System, New York, N. Y.
DeValve, H. C., Jr., Bell Tel. Labs., Inc., New York, N. Y.
DeWitt, R., Weston Elec. Instrument Corp., Newark, N. J.
DiMatteo, H. J., Board of Transportation, New York, N. Y.
diMonda, R., Atlantic Basin Iron Works, Brooklyn, N. Y.
Dougherty, R. L., Bell Tel. Labs., New York, N. Y.
Douglas, D. A., Columbia Broadcasting Co., New York, N. Y.
Emma, R. A., Federal Tel. & Radio Corp., Clifton, N. J.
Erickson, J. M., J. Livingston & Co., New York, N. Y.
Evenson, R. K., Bell Tel. Labs., New York, N. Y.
Farmer, R. B., Federal Tel. & Radio Corp., Clifton, N. J.
Fawwaz, R. A., Intl. General Elec. Co., New York, N. Y.
Fenichel, M., 582 Howard Avenue, Brooklyn, N. Y.
Finkel, A., Consolidated Edison Co., New York, N. Y.
Franchina, M. A., Langevin Mfg. Co., New York, N. Y.
Fristensky, C. A., Newark College of Engg., Newark, N. J.
Fruscione, J. M., New Jersey Bell Tel. Co., Vineland, N. J.
Furness, J., Sperry Gyroscope Co., Great Neck, N. Y.
Gelberg, A., Federal Elec. Prods. Co., Newark, N. J.
Girsch, S., N. Y. C. Dept. of Hospitals, New York, N. Y.
Gleimer, L., Remington Rand, Inc., New York, N. Y.
Gloister, R. F., Underwriter's Labs., New York, N. Y.
Goble, C. J., Western Elec. Co., Newark, N. J.
Goodman, B., Westchester Lighting Co., Mt. Vernon, N. Y.
Gosnell, F. L., Phelps Dodge Copper Prods. Corp., New York, N. Y.
Grace, E. J., Westinghouse Intl. Co., New York, N. Y.
Grossbohlin, H. W., A. B. Dumont Labs, Passaic, N. J.
Hansen, H. J., Crocker-Wheeler Elec. Mfg. Co., Ampere, N. J.
Harjes, R. H., New York Tel. Co., New York, N. Y.
Hers, H., Servo Corp. of America, Lindenhurst, L. I.
Higgins, R. T., Consolidated Edison Co., New York, N. Y.
Hochman, S., Sperry Gyroscope Co., Great Neck, L. I.
Hooper, D. E., Public Service Elec. & Gas Co., Newark, N. J.
Howe, B. A., Western Elec. Co., Newark, N. J.
Howell, F. H., Jr., American Gas & Elec. Service Corp., New York, N. Y.
Huggler, A. R., Federal Tel. & Radio Corp., Clifton, N. J.
Huguet, F. C., H. K. Ferguson Co., New York, N. Y.
Jacobson, L., Gibbs & Hill, Inc., New York, N. Y.
Jensen, H. F., N. Y. S. Inst. of Applied Arts & Sciences, Brooklyn, N. Y.
Johl, M. J., Standard Brands, Inc., New York, N. Y.
Kahn, A., Macy's Bureau of Standards, New York, N. Y.
Kahn, H. S., Fairchild Engine & Aircraft, Farmingdale, N. Y.
Kane, R. M., Westinghouse Elec. Corp., Bloomfield, N. J.
Kazan, J., General Elec. Co., Long Island City, N. Y.
Kingsley, B., Espey Radio Co., New York, N. Y.
Kolodny, I., General Cable Corp., New York, N. Y.
Kostalos, J., Jr., City College of New York, New York, N. Y.
Krainin, S., Natl. Broadcasting Co., New York, N. Y.
Kutner, H. B., Avion Instrument Corp., New York, N. Y.
Lakoski, T. J., Ward Leonard Elec. Co., Mt. Vernon, N. Y.
Lamb, C. W., Sperry Gyroscope Co., Great Neck, N. Y.
LaRosa, R., Hazeltine Electronics Corp., Little Neck, N. Y.
Leanza, V. C., Consolidated Edison Co., New York, N. Y.

Lewis, A. L., Public Service Elec. & Gas Co., of N. J., Newark, N. J.
Lewis, M. B., Western Union Tel. Co., New York, N. Y.
Lisiansky, W., 4600 Ninth Ave., Brooklyn, N. Y.
Locker, L., Voorhees, Walker, Foley & Smith, New York, N. Y.
Matsil, S., Board of Transportation, New York, N. Y.
McDonough, T. J., Western Elec. Co., Inc., New York, N. Y.
Menz, C. T., Jr., New York Tel. Co., Brooklyn, N. Y.
Meola, R. R., Newark College of Engr., Newark, N. J.
Milvaney, D. F., Intl. Business Machines Corp., New York, N. Y.
Moody, J. A., Sperry Gyroscope Co., Great Neck, N. Y.
Morris, D., Polarad Electronics Co., New York, N. Y.
Muha, W. J., Western Elec. Co., Newark, N. J.
Nachtigall, S., Mark Simpson Mfg. Co., Inc., L. I. C., N. Y.
Noel, J. O., Ebasco Services, Inc., New York, N. Y.
Orman, A., 38 Suffolk St., New York, N. Y.
Olivieri, E. S., Univ. of Puerto Rico, Mayaguez, Puerto Rico
Ost, S. B., Telephonics Corp., New York, N. Y.
Perez, P. G. J., Devenco, Inc., New York, N. Y.
Pool, R. M., Western Union Tel. Co., New York, N. Y.
Porter, J. C., American Tel. & Tel. Co., New York, N. Y.
Reynolds, A. C., Jr., Public Service Elec. & Gas Co., Newark, N. J.
Rosmoff, M., Western Elec. Co., Kearny, N. J.
Rubin, J. K., (Miss), Bell Tel. Labs., Inc., New York, N. Y.
Rutledge, J. E., Western Elec. Co., Kearny, N. J.
Salsburg, S. S., 75 Cumberland Walk, Brooklyn, N. Y.
Samuelian, B., Warner, Inc., New York, N. Y.
Scharf, J. K., Board of Transportation, New York N. Y.
Schnebbe, A. D., Rutgers Univ., New Brunswick, N. J.
Schooley, R. W., Jr., Reaction Motors, Inc., Dover, N. J.
Scott, E. E., Army-Navy Electronic & Elect. Standards Agency, Ft. Monmouth, N. J.
Selvaggi, P. S., Ford Instrument Co., Long Island City, N. Y.
Seman, K., 21 Elm Place, Hastings-on-Hudson, N. Y.
Sheard, W. G., Jr., Natl. Board of Fire Underwriters, New York, N. Y.
Sherich, E., Cornell-Dubilier Elec. Corp., So. Plainfield, N. J.
Silverman, A. J., 147-29 70th Ave., Kew Gardens, L. I., N. Y.
Simon, P., 1617 President St., Brooklyn, N. Y.
Smith, H. H., Fairchild Engine & Airplane Corp., Farmingdale, N. Y.
Smith, J. S., N. Y. Univ., New York, N. Y.
Smith, S., Fairchild Engine & Airplane Corp., Farmingdale, L. I., N. Y.
Sperry, P., C.C.N.Y. School of Tech., New York, N. Y.
Stolar, G., Newark College of Engg., Newark, N. J.
Swerlin, M., Board of Transportation, New York, N. Y.
Tice, A. R., Thomas A. Edison, Inc., West Orange, N. J.
Trimble, T. R., Underwriters' Laboratories, Inc., New York, N. Y.
Turner, R., Sperry Gyroscope Co., Great Neck, N. Y.
Vandiver, P. R., Atlantic City Elec. Co., Atlantic City, N. J.
van Dorsten, H. J., Westchester Lighting Co., Mt. Vernon, N. Y.
Ventosa, J. J., Board of Transportation, New York, N. Y.
Walder, B., N. Y. Univ., New York, N. Y.
Wallace, W., III, Ebasco Services, Inc., New York, N. Y.
Wassermann, C. I., Board of Transportation, New York, N. Y.
Weaver, P. F., Jr., Bell Tel. Labs., New York, N. Y.
Westman, H. F., Jr., Underwriters' Laboratories, Inc., New York, N. Y.
Wind, E., City College, New York, N. Y.
Wise, A., Brookhaven Natl. Lab., Upton, L. I., N. Y.
Witbeck, J. T., Otis Elevator Co., New York, N. Y.
Wittenberg, L., Bd. of Transportation, New York, N. Y.
Womble, A. K. (Miss), Intl. Business Mach., New York, N. Y.
Wright, R. Q., Buena Vista Heights, Suffern, N. Y.
Yudewitz, N., Frederick Sware Corp., N. Y. C.

4. Southern

Albus, J. W., Virginia Elec. & Power Co., Richmond, Va.
Alexander, J. G., Southern Bell Tel. & Tel. Co., Charlotte, N. C.
Alexander, C. H., Florida Power & Light Co., Stuart, Fla.
Ashby, C. W., Line Material Co., Birmingham, Ala.
Asquith, S. M., Jr., Graybar Elec. Co., Memphis, Tenn.
Averett, E. B., Jr., TVA, Chattanooga, Tenn.
Bailey, T. R., Univ. of Louisville, Louisville, Ky.
Bakst, A., Natl. Advisory Comm. for Aeronautics, Langley Field, Va.
Barnes, J. W., Lyman C. Reed, Inc., New Orleans, La.
Beard, C. C., Appalachian Elec. Power Co., Glen Lyn, Va.
Becker, C. L., Clemson Agricultural College, Clemson, S. C.
Berry, J. A., Jr., Carolina Power & Light Co., Goldsboro, N. C.
Brengartner, C. F., Dept. of Water & Power, Los Angeles, Calif.
Briney, G. S., Virginia Polytechnic Inst., Blacksburg, Va.
Brorein, W. J., So. Bell Tel. & Tel. Co., West Palm Beach, Fla.
Browning, L. L., Jr., R. J. Reynolds Tobacco Co., Winston-Salem, N. C.
Bryer, H., Jr., Best Elec. Co., New Orleans, La.
Buffett, R. K., TVA, Chattanooga, Tenn.
Burdsal, J. R., Kentucky-West Virginia Power Co., Hazard, Ky.
Burfoot, C. A., B. O. Vannort Co., Charlotte, N. C.
Burrus, G., Jr., Veterans Admin. Branch No. 4, Richmond, Va.
Burton, K. D., Northwestern Bell Tel. Co., Aberdeen, S. D.
Caldwell, W. S., TVA, Chattanooga, Tenn.
Chadwick, J. W., Jr., TVA, Jackson, Tenn.
Clark, R. F., Southern Bell Tel. & Tel. Co., Louisville, Ky.
Colgan, A. R., South Dakota School of Mines & Tech., Rapid City, S. Dak.
Cooper, W. A., Memphis, Tenn.
Cregar, C. J., Georgia Power Co., Atlanta, Ga.
Dabney, T. F., Carolina Power & Light, Asheville, N. C.
Davis, W. A., Jr., Alabama Power Co., Birmingham, Ala.
Dawson, E. B., Electrical Equipment Co., Augusta, Ga.
Dietrich, J. W., Texas A. & M. Research Foundation Lafitte, La.
Dimberg, P. A., Allis-Chalmers Mfg. Co., New Orleans, La.
Dobbins, J. G., S. C. Public Service Authority, Moncks Corner, S. C.
Douglas, B. J., E. Barrett Foster, C.E., Sheffield, Ala.
Dowdey, C. E., 809 South Maple St., Columbia, S. C.
Elliot, D. H., The D. H. Elliot Co., Inc., Roanoke, Va.
Eyman, D. R., Florida Power & Light Co., Miami, Fla.
Farabee, L. B., Mississippi State College, State College, Miss.
Fulton, W. L., Jr., Natl. Advisory Comm. for Aeronautics, Langley Field, Va.
Gordon, S. H., Melpar Inc., Alexandria, Va.
Granger, M. A., So. California Edison Co., Los Angeles, Calif.
Grever, J. L., Chanaberry Engg. Co., Louisville, Ky.
Gurley, E. L., Joseph E. Seagram & Sons, Inc., Louisville, Ky.
Harvey, B., L. B. Harvey Marine Instruments, Tampa, Fla.
Hatley, M. T., Jr., Duke Univ., Durham, N. C.
Helfron, W. G., Jr., Tulane Univ., New Orleans, La.
Herndon, R. H., TVA, Knoxville, Tenn.
Hill, G. F., Jr., Linde Air Products Co., Birmingham, Ala.
Hill, F. L., Fairchild Engine & Airplane Corp., Oak Ridge, Tenn.
Howard, J. D., Jr., Southern Bell Tel. & Tel. Co., Birmingham, Ala.
Howard, W. J., Jr., Standard Elec. Machine Works, Montgomery, Ala.
Huff, C. L., E. P. McLean Engg. Co., Moultrie, Ga.
Hughes, N. B., TVA, Chattanooga, Tenn.
Jamison, D. B., Southwestern Gas & Elec. Co., Shreveport, La.
Jared, H. G., TVA, Knoxville, Tenn.
Kalv, G. P., Florida East Coast Railroad, St. Augustine, Fla.
Kelley, R. S., Kelley Elec. Co., Lawrenceville, Ga.
Kirk, J. B., Alabama Power Co., Birmingham, Ala.
Kloga, P. J., Western Elec. Co., Inc., Winston-Salem, N. C.
Kraus, H. F., U. S. Engineers, New Orleans, La.
Lambie, J. W., Wagner Elec. Co., Miami, Fla.
Lewis, W. B., Clemson College, Clemson, S. C.
Lewis, T. E., Jr., The Girdler Corp., Louisville, Ky.
Marcum, J. A., The Ches. & Pot. Tel. Co. of Virginia, Richmond, Va.
McDaniel, T. J., Jr., Gaylor Elec. Service, Bogalusa, La.
McDaniel, T. S., Lanier Engg. Co., Troy, Ala.
Menius, E. F., Jr., Carolina Power & Light Co., Raleigh, N. C.
Moran, J. E., Ky. & W. Va. Power Co., Ashland, Ky.
Muir, R. C., Jr., Westinghouse Elec. Corp., Atlanta, Ga.
Nichols, L. L., Jr., Virginia Military Inst., Lexington, Va.
Parsons, R. L., Virginia Poly. Inst., Blacksburg, Va.
Peterson, W. J., Univ. of Tennessee, Knoxville, Tenn.
Pitts, H. F., Southern Elec. Service Co., Charlotte, N. C.
Redwine, F. R., TVA, Chattanooga, Tenn.
Renuen, P. A., Joseph E. Seagrams & Sons, Inc., Louisville, Ky.
Richardson, A., A. & T. College, Greensboro, N. C.
Rochet, C. E., Knoxville Utilities Board, Knoxville, Tenn.
Roy, E. F., Carbide & Carbon Chemicals Corp., Oak Ridge, Tenn.
Roy, E. H., Jr., Seaboard Air Line Railroad, Portsmouth, Va.
Sayad, J., Duke Univ., Durham, N. C.
Smith, E., Jr., Columbia High School, Columbia, S. C.
Smith, R. L., Jr., Mississippi State College, State College, Miss.
Speisegger, H. B., Jr., S. C. Power Co., Charleston, S. C.
Strickland, F. E., Jr., Robert & Co., Inc., Atlanta, Ga.
Stroud, H. N., Jr., TVA, Chattanooga, Tenn.
Stuck, R. D., Warren Wilson College, Swannanoa, N. C.
Stupalsky, A. J., Virginia Military Inst., Lexington, Va.
Sumpter, C. B., Jr., The Lane Co., Inc., Altavista, Va.
Sweeney, T. L., Lanier Engg. Co., Troy, Ala.
Swift, J. B., Louisville Gas & Elec. Co., Louisville, Ky.
Thompson, W. D., TVA, Memphis, Tenn.
Toothman, V. E., Ky. & W. Va. Power Co., Ashland, Ky.
Trimmer, R. E., Florida Power & Light Co., Miami, Fla.
Turbeville, J. R., Natl. Advisory Comm. for Aeronautics, Hampton, Va.
Van Dyke, W. H., Box 29, Tazewell, Va.
Walker, G. H., Carolina Power & Light Co., Asheville, N. C.
Waters, W. E., Jr., Univ. of Kentucky, Lexington, Ky.
Wenk, L. E., Southwestern Gas & Elec. Co., Shreveport, La.
Willard, W. E., Ethyl Corp., Baton Rouge, La.
Willhite, C. C., Bell Tel. Labs., Burlington, N. C.
Williams, T. B., Jr., Radio Station *WSJS*, Winston Salem, N. C.
Willis, J. W., Engg. Research Assocs., Inc., Arlington, Va.
Wilson, W. E., 104 Demetree Bldg., Tallahassee, Fla.
Wooldridge, L. C., Memphis Light, Gas & Water Div., Memphis, Tenn.
Woolley, C. B., Jr., TVA, Chattanooga, Tenn.
Wuchte, R. E., Intl. Business Machines, Raleigh, N. C.
Zoellers, C. A., Ky. & W. Va., Power Co., Inc., Hazard, Ky.

5. Great Lakes

Ackerman, N. A., Chicago Technical College, Chicago, Ill.
Allbaugh, K. R., Iowa Public Service Co., Waterloo, Iowa
Amster, H. B., Purdue Univ., W. Lafayette, Ind.
Andringa, B. C., Allen Bradley Co., Milwaukee, Wis.
Ardery, J. E., Northwestern Public Service Co., Mitchell, S. Dak.
Atkinson, G. L., Line Material Co., Milwaukee, Wis.
Babb, D. S., Univ. of Illinois, Urbana, Ill.
Balliette, R. H., Commonwealth Tel. Co., Madison, Wis.
Belsky, E. W., Jr., Automatic Elec. Co., Chicago, Ill.
Bennett, C. C., General Motors, LaGrange, Ill.
Benson, R., Public Service Co. of No. Ill., Maywood, Ill.
Bernin, V. M., Communication Equipment & Engg. Co., Chicago, Ill.
Best, A. G., Iowa Elec. Light & Power Co., Boone, Iowa
Blanchard, B. K., Bucyrus-Erie Co., South Milwaukee, Wis.
Blankenbaker, F. A., Jr., Prehler Elec. Insulation Co., Minneapolis, Minn.
Bocchiardi, J., Illinois Power Co., Belleville, Ill.
Bond, N. T., Delta Star Elec. Co., Chicago, Ill.
Brabb, J. M., General Motors Corp., Flint, Mich.
Bradford, C. H., Public Lighting Comm., Detroit, Mich.
Bradley, E. L., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Buchberger, A. C., Square D Co., Milwaukee, Wis.
Buck, H. B., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Burns, R. F., Univ. of Illinois, Urbana, Ill.
Carlson, W. E., Corn Prod. Refining Co., Argo, Ill.
Clarkson, R. C., Public Lighting Comm., Detroit, Mich.
Collis, S. R., Illinois Bell Tel. Co., Chicago, Ill.
Commy, P. G., Commy Engg. Co., Fargo, N. Dak.
Conrad, A. F., DeForest Training Inc., Chicago, Ill.
Corrigan, J. J., War Assets Admn., Chicago, Ill.
Council, L. B., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Cramer, R. F., Grundy County Rural Elec. Coop., Grundy Center, Iowa
Cummings, K. C., Minneapolis Honeywell Reg. Co., Minneapolis, Minn.
Davis, R. R., Rome Cable Corp., Chicago, Ill.
Dartnall, R. D., General Elec. Co., Ft. Wayne, Ind.
Dieterle, R. C., Cutler-Hammer, Inc., Milwaukee, Wis.
Dittus, R. W., Electrical Engrs. Equipment Co., Melrose Park, Ill.
Doyle, E. J., Illinois Bell Tel. Co., Chicago, Ill.
Drnek, J. L., Barber-Colman Co., Rockford, Ill.
Dudash, J. G., Ford Motor Co., Dearborn, Mich.
Eckerle, H. F., Jr., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Eckert, J. G., Bell Tel. Co., Detroit, Mich.
Erickson, W. E., Kaiser-Frazer Corp., Willow Run, Mich.
Fenaughty, A. L., Jr., Engg. Research Assocs., Inc., St. Paul, Minn.
Figg, C. F., Delco-Remy, Anderson, Ind.
Francis, R. R., Allis-Chalmers Mfg. Co., West Allis, Wis.
Frederickson, C. A., Streeter Amet Co., Chicago, Ill.
Gifford, G. R., Public Service Co., Northern Illinois, Chicago, Ill.

Gilden, M., Illinois Inst. of Tech., Chicago, Ill.
Glass, E. C., Northern States Power Co., Minneapolis, Minn.
Godar, A. A., Allis-Chalmers Mfg. Co., West Allis, Wis.
Goetz, L., Collins Radio Co., Cedar Rapids, Iowa
Golffon, D. P., Wisconsin Power & Light Co., Madison, Wis.
Goldberg, Y. (re-election), Iowa Power & Light Co., Des Moines, Iowa
Goosman, T. E., Factory Insurance Assn., Chicago, Ill.
Hagenberg, R. J., Standard Oil Co., Whiting, Ind.
Harris, D. H., Iowa Public Service Co., Sheldon, Iowa
Harrower, T. M., Westinghouse Elec. Corp., Chicago, Ill.
Hart, W. N., Michigan State College, E. Lansing, Mich.
Hausladen, H. L., Western Elec. Co., Duluth, Minn.
Hazen, R. H., Commonwealth & Southern Corp., Jackson, Mich.
Hellar, M. W., Jr., General Elec. Co., Ft. Wayne, Ind.
Henehan, J. F., Nash-Kelvinator Corp., Detroit, Mich.
Hill, C. F., Sargent & Lundy, Chicago, Ill.
Hinz, D. J., Engg. Research Assocs., Inc., St. Paul, Minn.
Hitzenhammer, A. deV., Civil Aeronautics Admin., Chicago, Ill.
Hoge, H. D., Line Material Co., So. Milwaukee, Wis.
Hollingshead, H. K., Iowa Elec. Light & Power Co., Cedar Rapids, Iowa
Horgan, J. S., Micromatic Hone, Inc., Detroit, Mich.
Hovland, R. W., Public Service Co. of No. Ill., Joliet, Ill.
Hubbard, W. C., Iowa-Ill. Gas & Elec. Co., Rock Island, Ill.
Humphreys, D. S., The Magnavox Co., Ft. Wayne, Ind.
Hurwitz, M. L., Automatic Elec. Co., Chicago, Ill.
Isaacson, J., Waters Conley Co., Rochester, Minn.
Johnson, C. F., Jr., Mfg. Co., Michigan City, Ind.
Johnson, L. C., Automatic Elec. Co., Chicago, Ill.
Johnson, O. D., Sears, Roebuck & Co., Chicago, Ill.
Johnson, R. H., Jr., Illinois Bell Tel. Co., Danville, Ill.
Keefer, H. D., Aluminum Co. of America, E. St. Louis, Ill.
Keidel, R. A., A. O. Smith Corp., Milwaukee, Wis.
King, L. H., Pioneer Service & Engg. Co., Chicago, Ill.
Kocik, J., Jr., Illinois Bell Tel. Co., Chicago, Ill.
Kohan, A., Michigan Bell Tel. Co., Detroit, Mich.
Kolom, L. L., American Television, Inc., Chicago, Ill.
Kostuck, V., Jr., Cutler-Hammer Corp., Milwaukee, Wis.
Kozinski, W. S., Commonwealth Edison Co., Chicago, Ill.
Kramme, J. W., Indianapolis Power & Light, Indianapolis, Ind.
Kratochvil, J. A., Western Elec. Co., Chicago, Ill.
Krezmar, J., 202 North 34 St., Milwaukee, Wis.
Kryskalla, C. F., Public Lighting Comm., Detroit, Mich.
Lamb, E. R., Wisconsin Tel. Co., Milwaukee, Wis.
Lamb, F. J., Detroit Edison Co., Detroit, Mich.
Lapin, J. L., Belmont Radio Corp., Chicago, Ill.
Latimer, J. C., General Elec. Co., Ft. Wayne, Ind.
Leighton, J. R., Northwestern Bell Tel. Co., Austin, Minn.
Lindsay, A., Public Service Co. of No. Ill., Chicago, Ill.
Loeffler, A. F., Jr., Line Material Co., So. Milwaukee, Wis.
Lund, H. S., Mich. College of Mining & Tech., Sault Ste. Marie, Mich.
Mabry, G. R., American Tel. & Tel. Co., Chicago, Ill.
MacGregor, R. J., Shell Oil Co., Wood River, Ill.
Macrae, R. J., Macy's Dept. Store, Milwaukee, Wis.
Markey, L. T., Jr., Western Elec. Co., Chicago, Ill.
Marx, E. A., Allen-Bradley Co., Milwaukee, Wis.
Maxwell, B. M., Jr., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
McCartney, E. L., Public Service Co. of No. Illinois, Maywood, Ill.
McHugh, J. J., Commonwealth Edison Co., Chicago, Ill.
McNeil, J. I., Jensen Bowen & Farrell Co., Ann Arbor, Mich.
Mericle, M. H., Republic Steel Corp., Chicago, Ill.
Millhollin, L. M., Jr., Western Union Tel. Co., Chicago, Ill.
Miller, J. B., Univ. of Wisconsin, Madison, Wis.
Miller, R. E., Willow Run Airport, Ypsilanti, Mich.
Modrzejewski, E. J., Milwaukee School of Engg., Milwaukee, Wis.
Montoure, E. J., Gimbel Bros., Milwaukee, Wis.
Moscle, M. F. (re-election), Public Service Co. of No. Illinois, Chicago, Ill.
Mosley, N. G., Shell Oil Co., Inc., Wood River, Ill.
Mueller, R. F., Micheal Reese Hospital, (Univ. of Ill.), Champaign, Ill.
Narum, E. R., Allis-Chalmers Mfg. Co., West Allis, Wis.
Nawn, B. D., Marquette Univ., Milwaukee, Wis.
Nelson, J. W., Jr., Westinghouse Elec. Corp., Duluth, Minn.
Nicholson, J. D., Indiana Bell Tel. Co., Indianapolis, Ind.
O'Hara, F. D. T., DuPont Cellophane Div., Clinton, Iowa
Owen, C. T., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Panuck, H. R., Univ. of Michigan, Ann Arbor, Mich.
Pease, F. X., Western Elec. Co., Chicago, Ill.
Parent, G. O., General Elec. Co., Ft. Wayne, Ind.
Parker, C. W., Jr., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Pavcla, H. W., Armour Research Foundation, Chicago, Ill.
Pedersen, K. W., Automatic Elec. Co., Chicago, Ill.
Peltola, Y. K., Illinois Testing Labs. Inc., Chicago, Ill.
Perkins, W. L., Natural Gas Pipeline Co. of America, Chicago, Ill.
Piesaule, P. L., Elec. Engrs. Equipment Co., Melrose Park, Ill.
Powers, J. N., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Preston, S. H., Schaefer Elec. Co., Inc., Peoria, Ill.
Rachofsky, A. L., Pioneer Service & Engg. Co., Chicago, Ill.
Ricci, N. A., Wisconsin Elec. Power Co., Milwaukee, Wis.
Richardson, D. L., Caterpillar Tractor Co., Peoria, Ill.
Richter, F. A., Hotpoint Inc., Chicago, Ill.
Ringstrand, R. C., Wisconsin Tel. Co., Madison, Wis.
Robertson, J. P., American Tel. & Tel. Co., Des Moines, Iowa
Robinson, M. D., Carnegie-Illinois Steel, Gary, Ind.
Rodewald, L. E., Minnesota Power & Light Co., Duluth, Minn.
Roggenkamp, G. H., Pyle National Co., Chicago, Ill.
Rosenbarker, I. E., Intl. Business Machine Corp., Chicago, Ill.
Rush, B. B., Great Lakes Steel Corp., Ecorse, Mich.
Russell, W. A., S. E. Iowa Cooperative Elec. Assn., Mt. Pleasant, Iowa
Ryan, R. E., J. F. Fisher Co., Chicago, Ill.
Samuelson, D. D., Northwestern Univ., Evanston, Ill.
Sawyer, W. E., Western Elec. Co., Cicero, Ill.
Scheinberg, L. R., General Elec. X-Ray Corp., Milwaukee, Wis.
Schlein, H., Wisconsin Elec. Power Co., Milwaukee, Wis.
Schneemann, H. T., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Sedore, J. H., Iowa Elec. Light & Power, Cedar Rapids, Iowa
Sexauer, P. S., The Detroit Edison Co., Detroit, Mich.
Shapiro, N., Public Lighting Comm., Detroit, Mich.
Shintani, E. H., Sinclair Refinery Co., E. Chicago, Ind.
Shreck, B. B., D. E. K. Rural Elec. Cooperative, Estherville, Iowa
Siddiqui, M. O., 1101 West Illinois St., Urbana, Ill.
Siemianowski, E. J., Standard Transformer Corp., Chicago, Ill.
Silverson, J. D., 545 Second St., Calumet, Mich.
Slear, E. K., Public Lighting Comm., Detroit, Mich.
Smith, F. A., Kuhlman Elec. Co., Bay City, Mich.
Somers, D. F., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Somes, F. J., Jr., Hydon-Brand Co., Detroit, Mich.
Sovick, F. J., Oliver Iron Mining Co., Duluth, Minn.
Spengler, J., Illinois Power Co., Decatur, Ill.
Squillace, S. S., City of Detroit, Detroit, Mich.
Stauffer, F. E., Illinois Northern Utilities Co., Dixon, Ill.
Streich, L. F., Wisconsin Tel. Co., Madison, Wis.
Taylor, R. W., Public Service Co. of No. Ill., Maywood, Ill.
Tice, G. A., Cutler Hammer, Inc., Milwaukee, Wis.
Tow, R. L., Hartford Accident & Indemnity Co., Des Moines, Iowa
Turner, F. D., Public Service Co. of No. Ill., Joliet, Ill.
Tyler, L. D., General Motors Corp., Indianapolis, Ind.
Vandernuss, R. L., The Vollrath Co., Sheboygan, Wis.
Veith, D. J., Standard Oil Co., Whiting, Ind.
Verdeyen, F. J., Indianapolis Power & Light Co., Indianapolis, Ind.
Walley, J. A., General Elec. Co., Ft. Wayne, Ind.
Walters, G., General Elec. Co., Ft. Wayne, Ind.
Webb, D. W., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Wetters, D. D., Delco Prods. Div. of G. M. C., Dayton, Ohio
Williams, G. O., Hobart Bros. Co., Troy, Ohio
Williams, P. S., Univ. of Minn., Minneapolis, Minn.
Willis, G. R., Waters-Conley Co. Lab., Rochester, Minn.
Woodmansee, J. M., Elec. Engrs. Equipment Co., Melrose Park, Ill.
Wright, R. O., Republic Steel Corp., Chicago, Ill.
Wuerl, W. W., Square D. Company, Milwaukee, Wis.
Zucker, R. E., General Elec. Co., Ft. Wayne, Ind.

6. North Central

Beach, B. C., Jr., Bureau of Reclamation, Denver, Colo.
Berg, R. A., Schneider Elec. Works, Omaha, Nebr.
Berner, R. W., Consumer's Public Power Dist., O'Neill, Nebr.
Carey, R. B., Union Pacific Railroad Co., Omaha, Nebr.
Evans, D. W., Univ. of Colorado, Boulder, Colo.
Flores, J., U. S. Bureau of Reclamation, Denver, Colo.
Flyr, J. G., Radio Station KFAB, Lincoln, Nebr.
Goldberg, H. M., Univ. of Denver, Denver, Colo.
Guerber, H. P., Univ. of Colorado, Boulder, Colo.
Hall, G. L., General Elec. Co., Denver, Colo.
Hardung, L. D., Northwestern Bell Tel. Co., Omaha, Nebr.
Kilburz, M. E., Omaha Public Power District, Omaha Nebr.
Klein, F. A., American Tel. & Tel., Co., Denver, Colo.
Korte, J. W., Northwestern Bell Tel. Co., Omaha, Nebr.
Massie, P. E., 1224 No. 46 Street, Lincoln, Nebr.
Mott, W. H., General Elec. Co., Denver, Colo.
Partridge, N. R., Mountain States Tel. & Tel. Co., Cheyenne, Wyo.
Perry, G. D., Jr., Pueblo Junior College, Pueblo, Colo.
Robinson, R. R., American Tel. & Tel., Denver, Colo.
Schaefer, E. H., Univ. of Colo., Denver, Colo.
Schrader, D. L., Stearns Roger Mfg. Co., Denver, Colo.
Vinze, S. N., U. S. Bureau of Reclamation, Denver, Colo.
Winthrop, A. S., U. S. Bureau of Reclamation, Denver, Colo.

7. South West

Anderson, J. W., Oklahoma Elec. Cooperative (REA), Norman, Okla.
Benson, I. A., Southwestern Public Service Co., Amarillo, Tex.
Capshaw, T. D., Texas Elec. Service Co., Ft. Worth, Tex.
Cash, F. L., Hardin College, Wichita Falls, Tex.
Crary, J. F., Kansas State College, Manhattan, Kans.
Grice, H. E., Southwestern Bell Tel. Co., Dallas, Tex.
Cummins, W. A., Southwestern Public Service Co., Canyon, Tex.
Davis, M. N., Oklahoma Gas & Elec. Co., Ardmore, Okla.
Denton, D. M., The Texas Co., Perryton, Tex.
Dorsett, H. L., 601½ West Eufaula, Norman, Okla.
Evans, J. H., Southwestern Public Service Co., Borger, Tex.
Fisher, R. B., Geophysical Research Corp., Tulsa, Okla.
Frank, D. W. (re-election), Standard Oil & Gas Co., Tulsa, Okla.
Frank, M. E., Tennessee Gas Transmission Co., Houston, Tex.
Gibson, R. S., Fire Prevention & Engg. Bureau of Texas, Dallas, Tex.
Hallford, B. R., Station *KRLD*, Dallas, Tex.
Halter, G. S., City Public Service Board, San Antonio, Tex.
Hassinger, E. V., Lower Colorado River Authority, Austin, Tex.
Helland, J. C., Boeing Airplane Co., Alamogordo, New Mex.
Holmes, H. T., Arkansas Power & Light, Stamps, Ark.
Howell, J. K., Westinghouse Elec. Corp., St. Louis, Mo.
Jordan, W. D., Texas Elec. Service Co., Ft. Worth, Tex.
Kageler, A. M., Jr., Pan American Refg. Corp., Texas City, Tex.
Kern, H. O., Westinghouse Elec. Corp., St. Louis, Mo.
Kneedler, H. A., Guarantee Elec. Co., St. Louis, Mo.
Lee, M. R., City of Lubbock, Lubbock, Tex.
Lipin, B., Black & Veatch Consulting Engrs., Kansas City, Mo.
Love, C. O., Texas Power & Light Co., Hillsboro, Tex.
Ludwig, R. W., Univ. of Texas, Austin, Tex.
Mabe, J. M., Central Power & Light Co., San Benito, Tex.
Mast, C. A., Central Power & Light Co., Laredo, Tex.
McDermott, E. P., Arkansas Power & Light Co., Searcy, Ark.
Montgomery, C. D., Univ. of California, Los Alamos, N. Mex.
Moriaty, J. D., Gulf Oil Corp., Port Arthur, Tex.
Nelson, R. K., South Western Bell Tel. Co., Dallas, Tex.
Ochsner, J. H., Union Elec. Co. of Missouri, St. Louis, Mo.
Otteser, J., Westinghouse Elec. Corp., St. Louis, Mo.
Packard, R. M., Dallas Power & Light Co., Dallas, Tex.
Paula, G. C., Petrolite Corp.-Tretrolite Co., Webster Groves, Mo.
Poole, W. S., Poole Instruments Inc., Dallas, Tex.
Poundstone, D. M., Phillips Petroleum Co., Borger, Tex.
Reed, M. C., Southwestern Bell Tel. Co., Oklahoma City, Okla.
Reiff, J. C., Univ. of New Mexico, Albuquerque, N. Mex.
Remy, C. W., American Tel. & Tel. Co., St. Louis, Mo.
Riggs, M. M., Ark. Power & Light Co., Hot Springs, Ark.
Ritow, I., White-Rodgers Elec. Co., St. Louis, Mo.
Rudasill, R. H., Central Power & Light Co., San Benito, Tex.
Seneff, H. L., Jr., Univ. of Missouri, Columbia, Mo.
Shelton, C. E., Oklahoma Gas & Elec. Co., Ardmore, Okla.
Slaughter, E., Jr., Gulf States Utilities, Beaumont, Tex.
Smith, S. C., Southwestern Gas & Elec. Co., Fayetteville, Ark.
Smitherman, R. S., Southwestern Gas & Elec. Co., Texarkana, Tex.
Stout, T. M., Emerson Elec. Mfg. Co., St. Louis, Mo.
Sundt, W. M., Univ. of Calif., Sandia Base, Albuquerque, N. Mex.
Swanson, R. D., Western Union Tel. Co., Dallas, Tex.

Thompson, R. J., Carnahan & Thompson Engineers, Oklahoma City, Okla.
Trewitt, M. B., Station *WFAA*, Dallas, Tex.
Tuttle, E. J., Oklahoma Gas & Elec. Co., Oklahoma City, Okla.
Wallace, M. L., General Elec. Co., Dallas, Tex.
Watts, J. H., Jr. (re-election), Westinghouse Elec. Corp., Corpus Christi, Tex.
Weinstein, D. H., The Superior Oil Co., Houston, Tex.
Westervelt, G. C., Freese & Nichols, Fort Worth, Tex.
York, C. L., Station *KFRM*, Concordia, Kans.

8. Pacific

Balzer, E. W. (re-election), Public Utilities, San Francisco, Calif.
Barauck, A. H., Pacific Gas & Elec. Co., San Francisco, Calif.
Barbour, M. T., Dept. of Water & Power, Los Angeles, Calif.
Barnes, R. P., Westinghouse Elec. Corp., San Francisco, Calif.
Bishop, N. S., Northrop Aircraft Co., Hawthorne, Calif.
Blink, R. L., Westinghouse Elec. Corp., Emeryville, Calif.
Cohen, A., National Schools, Los Angeles, Calif.
Conklin, J. S., So. California Edison Co., Los Angeles, Calif.
Cool, L. R., California State Polytechnic College, San Luis Obispo, Calif.
Cordes, H. W., Southern California Edison Co., Los Angeles, Calif.
Coulter, J. C., Pacific Gas & Elec. Co., Oakland, Calif.
Cox, J. A., U. S. Elec. Motors, Los Angeles, Calif.
Darsey, M. H., Univ. of California, Berkeley, Calif.
Dooroff, A. N., Long Beach Naval Shipyard, Long Beach, Calif.
Fifer, R. D., Jr., Pacific Gas & Elec. Co., Stockton, Calif.
Fischer, H. D., Jr., Southern Calif. Edison Co., Los Angeles, Calif.
Fladvy, E. L., 1919 Tenth St., Berkeley, Calif.
Frazier, E., F. Krause & Co., Alhambra, Calif.
Freebairn, D., Jr., North American Aviation Inc., Inglewood, Calif.
Giel, G. J., Jr., Berkeley Scientific Co., Richmond, Calif.
Girard, A. A., Pacific Gas & Elec. Co., San Francisco, Calif.
Greenhill, C. W., San Diego Gas & Elec. Co., San Diego, Calif.
Hagbloom, E. H., 668 W. 9th Street, San Bernardino, Calif.
Harlan, L. R., Permanente Cement Co., Permanente, Calif.
Harrington, G. R., Shell Chemical Corp., Wilmington, Calif.
Hessler, W. G., Jr., GHQ, FEC, APO No. 500, c/o PM, San Francisco, Calif.
Hinrichs, K., Univ. of California, Berkeley, Calif.
Holloway, R. A., Lockheed Aircraft Corp., Burbank, Calif.
Hopper, W. B., L. S. Rosener, San Francisco, Calif.
Horton, J. R., Dibert Elec. Co., Phoenix, Ariz.
Hunziker, R. W., Underwriters' Laboratories, Inc., San Francisco, Calif.
Jeter, C. T., U. S. Bureau of Reclamation, Redding, Calif.
Jones, R. J., Brown-Pacific-Maxon, San Francisco, Calif.
Khazoyan, B. B., Westinghouse Elec. Corp., Los Angeles, Calif.
King, H. R., Dept. of Water & Power, Los Angeles, Calif.
Klassen, R. F., Standard Oil Co. of Calif., La Habra, Calif.
Lee, A. E., 1988 San Antonio Rd., Berkeley, Calif.
Leino, F. E., McDougald & Leino, C. E., Fresno, Calif.
Liljeberg, J. J., Standard Oil Co. of Calif., San Francisco, Calif.
Lyons, F. L., Northrop Aircraft, Inc., Hawthorne, Calif.
Marr, W. L., Pacific Gas & Elec. Co., Stockton, Calif.
Marxheimer, R. B., Pacific Gas & Elec. Co., San Fransisco, Calif.
McCombs, C. C., Natl. Advisory Comm. for Aeronautics, Moffett Field, Calif.
McCulloch, J. H., Stanford Univ., Calif.
Mcinig, R. O., Pacific Power & Light Co., Yakima, Wash.
Moon, G. F., Pacific Gas & Elec. Co., Oakland, Calif.
Murray, W. E., C. F. Braun & Co., Alhambra, Calif.
Nettesheim, H. P., Univ. of Santa Clara, Santa Clara, Calif.
Nichols, N., Westinghouse Elec. Corp., Los Angeles, Calif.
Nourse, R. B., Dept. Water & Power, Los Angeles, Calif.
Parks, E., San Diego Gas & Elec. Co., San Diego, Calif.
Paul, R. J., Pacific Tel. & Tel. Co., Los Angeles, Calif.
Reed, D. E., California Div. of Highways, San Luis Obispo, Calif.
Regan, P. W., Raisch Paving Co., San Jose, Calif.
Richardson, T., U. S. Engrs., San Francisco, Calif.
Rosa, G. N., Statham Labs., Los Angeles, Calif.
St. Clair, H. K., Univ. of California, Berkeley, Calif.
Sawyer, H. F., Westinghouse Elec. Corp., Sunnyvale, Calif.
Schmidt, J. N., North American Aviation Inc., Los Angeles, Calif.
Schmidt, P. H., City of Palo Alto, Calif.
Schrader, W. G., U.S.B.R. Shasta Dam Power Plant, Redding, Calif.
Schultz, E. E., Atlas Elec. Engg. Co., San Francisco, Calif.
Seaman, J. R., So. California Edison Co., Alhambra, Calif.
Seidman, J. J., Univ. of So. California, Los Angeles, Calif.
Selvage, C. S., Westinghouse Elec. Corp., Los Angeles, Calif.
Singh, R. B., Bureau of Engg. Municipal Ry., San Francisco, Calif.
Stearns, J. M., Pacific Gas & Elec. Co., Marysville, Calif.
Stewart, D., Jr., Metropolitan Water Dist. of So. California, Earp, Calif.
Stolmack, H. W., Columbia Steel Corp., Pittsburgh, Calif.
Stroud, S. G., McCullough Tool Co., Los Angeles, Calif.
Tanner, A. E., Jr., San Francisco Public Utilities Comm., San Francisco, Calif.
Trescony, L. J., R. E. Davis, Berkeley, Calif.
Vornbrun, W., U. S. Navy, San Diego, Calif.
Werts, L. C., Rev., S.J., Loyola Univ., Los Angeles, Calif.
Whalen, K. H., Pacific Gas & Elec. Co., San Francisco, Calif.
Wilson, J. R., U. S. Navy Air Missile Test Center, Point Mugu, Calif.
Wintz, E. V., Factory Insurance Assn., Los Angeles, Calif.
Wolfe, H. T., Pacific Tel. & Tel. Co., Berkeley, Calif.
Wong, R. B. Y., Pacific Gas & Elec. Co., San Francisco, Calif.
Yeranian, A. S. (re-election), Pacific Gas & Elec. Co., San Francisco, Calif.

9. North West

Arnett, K. B., Pacific Elec. Sales, Inc., Portland, Oreg.
Bannon, C. F., City Light Co., Seattle, Wash.
Beard, J. G., Jr., Phelps Dodge Copper Prods. Corp., Clifton, Ariz.
Bonar, W. W., Portland General Elec. Co., Portland, Oreg.
Brown, R. J., Bonneville Power Admn., Portland, Oreg.
Busby, F. M., Alaska Comm. System (U. S. Army), Seattle, Wash.
Conrad, R. F., The Pacific Tel. & Tel. Co., Portland, Oreg.
Dorwart, R. J., General Elec. Co., Hanford, Wash.
Frazer, K. J., Montana Power Co., Helena, Mont.
Fyhrie, G., Washington Water Power, Spokane, Wash.
Gonnason, J. A., Civil Aeronautics Admin., Anchorage, Alaska
Jacobsen, R. G., Univ. of Washington, Seattle, Wash.
Jett, R. E., Pacific Tel. & Tel. Co., Portland, Oreg.
Jones, E. S., Telluride Power Co., Richfield, Utah
Korte, R. M., Greenacres, Wash.
Merryweather, K. A., Columbia Elec., Spokane, Wash.
Mittendorf, J. A., Pacific Tel. & Tel. Co., Seattle, Wash.
Mukerji, M. M., Univ. of Washington, Seattle, Wash.
O'Brien, D. J., Montana Power Co., Great Falls, Mont.
Patrick, R. S., Utah Power & Light Co., Salt Lake City, Utah
Servold, A. W., Pacific Portland Cement Co., Gold Hill, Oreg.
Silver, L. R., Clarence W. Silver Co., Salt Lake City, Utah
Winsor, H. J., Weyerhaeuser Timber Co., Tacoma, Wash.

10. Canada

Adamson, D., Shawinigan Water & Power Co., Shawinigan Falls, Quebec, Canada
Bourque, C., Aluminum Co. of Canada, Shawinigan Falls, Quebec, Canada
Caldwell, L. W., Jr., Canadian General Elec. Co., Ltd., Toronto, Ontario, Canada
Carignan, L. G., Erepeau, Cote & Lemieux, Lachine, Quebec, Canada
Chambers, J. B., Natl. Research Council, Ottawa, Ontario, Canada
Cook, R. E., Imperial Oil Limited, Edmonton, Alberta, Canada
Cooper, E. E., Imperial Oil Ltd., Edmonton, Alberta, Canada
Cox, R. A., B. C. Electric Co., Ltd., Vancouver, British Columbia, Canada
Creelman, E. A., W. L. Stevens, New Westminster, British Columbia, Canada
Dupuis, J. J., Consolidated Paper Co., Shawinigan Falls, Quebec, Canada
Fitzallen, J. H., Toronto Transportation Comm., Toronto, Ontario, Canada
Gilbert, G. R., Shawinigan Chemicals, Ltd., Shawinigan Falls, Quebec, Canada
Gleig, S. B., British Columbia Railway Co., Vancouver, British Columbia, Canada
Henrikson, G. J., British Columbia Elec. Railway Co., Vancouver, British Columbia, Canada
Hesla, E. C., Canadian General Elec., Peterborough, Ontario, Canada
Horne, L. R., British Columbia Elec. Railway Co., Vancouver, British Columbia, Canada
Kane, E. J., Canada General Elec. Co., Ltd., Toronto, Ontario, Canada
Kent, N. S., British Columbia Elec. Railway Co. Vancouver, British Columbia, Canada
Kirkpatrick, G. G., Canadian General Elec., Peterborough, Ontario, Canada
Langenek, F., British Columbia Railway Co., Vancouver, British Columbia, Canada
Laperriere, J. M., Shawinigan Water & Power Co., Shawinigan Falls, Quebec, Canada
Lavallee, R., Aluminum Co. of Canada, Ltd., Shawinigan Falls, Quebec, Canada
Lewis, W. R., Hydro-Elec. Power Comm. of Ont., Toronto, Ontario, Canada
Mabson, H. J., Bell Tel. Co. of Canada, Toronto, Ontario, Canada
MacNeil, C. P., Elec. Tamper & Equip. Co., Montreal, Quebec, Canada
Marcotte, W. C., Elec. Reduction Co., Buckingham, Quebec, Canada
Markow, G. R., Canada Wire & Cable Co., Ltd., Toronto, Ontario, Canada
McClymont, K. R., Univ. of Toronto, Toronto, Ontario, Canada
McCullough, K., Turnbull Elevator Co., Ltd., Toronto, Ontario, Canada
McGregor, B. H., Northern Elec. Co., Ltd., Belleville, Ontario, Canada
McHattie, G. T., British Columbia Elec. Co., Vancouver, British Columbia, Canada
Meloche, R., Southern Canada Power Co., Ltd., Montreal, Quebec, Canada
Meredith, B. E. (Miss), Univ. of Toronto, Toronto, Ontario, Canada
Morham, K. L., Aluminum Co. of Canada, Shawinigan Falls, Quebec, Canada
Procunier, G. W., Canadian General Elec. Co., Toronto, Ontario, Canada
Read, P. C., Consolidated Paper Co., Three Rivers, Quebec, Canada
Regniere, J. A. (re-election), The Shawinigan Water & Power Co., Montreal, Quebec, Canada
Remilland, R. S., Aluminum Co. of Canada, Montreal, Quebec, Canada
Riopelle, R., Metropole Elec. Inc., Montreal, Quebec, Canada
Robertson, J. D., Brown Corp., LaTuque, Quebec, Canada
Scharry, L., Sangamo Co., Montreal, Quebec, Canada
Seppala, K. H. W., Canadian General Elec. Co., Ltd., Peterborough, Ontario, Canada
Simpson, J. B., Northern Elec. Co., Ltd., Three Rivers, Quebec, Canada
Stevenson, T., The Shawinigan Water & Power Co., Three Rivers, Quebec, Canada
Stewart, W. C., Shawinigan Water & Power Co., Shawinigan Falls, Quebec, Canada
Stringer, R. J., British Columbia Elec. Railway Co., Vancouver, British Columbia, Canada
Tate, R. S., Canadian General Elec. Co., Toronto, Ontario, Canada
Taylor, J. G., Hydro Elec. Power Comm. of Ont., Toronto, Ontario, Canada
Thornton, C. R., Canadian Line Materials Ltd., Ottawa, Ontario, Canada
Trudel, L., Dept. of Mines, Quebec, Quebec, Canada
Urquhart, R. R., Hydro Elec. Power Comm. of Ont., Toronto, Ontario, Canada
Walker, R. J., Dominion Textile Co., Montreal, Quebec, Canada
York, F. G., Ottawa Hydro-Elec. Comm., Ottawa, Ontario, Canada

**Elsewhere**

Ali, S. M., Madras Elec. Dept., India, c/o Natl. Provincial Bank Ltd., Stafford, England
Ananthvan, R., Chittoor Elec. Supply Corp., Ltd., Chittoor, Madras Presidency, South India
Beck, R. N., Metropolitan-Vickers Elec. Co., Ltd., Manchester, England
Behl, M. M., c/o L. Dharm Bir Behl, New Delhi, India
Cotterill, D. S., W. H. Smith & Co., Elect. Engg. Ltd., Manchester, England
Dass, S. K., Rohtas Industries, Ltd., Bihar, India
Haddad, I. S., Trans Arabian Pipeline Co., Beirut, Lebanon
Ingram, V. J., U. S. Army, Ft. Cleyton, Canal Zone
Janakiram, K. G., Arthur Hope College of Technology, Coimbatore, S. India
Kavruk, M. A. Reyrolle & Co., Hebburn Co., Durham, England
Klima, V., Moravian Elec. Engg. Works, Olomouc, Czechoslovakia
Knight, H. W. (re-election), North Met. Elec. Power Co., Brimsdown, Middlesex, England
Lever-Naylor, T. B., N. Z. Govt. Railways, Wellington, New Zealand
Mehta, S. F., M/S Siemens Brothers & Co., Ltd., Fort, Bombay, India
Mohammed, S. P., Government of Travancore, India
Nair, K. R., The Shenkottah Elec. Supply Agency, Punalur, Travancore, India
Ramani, R. V., Sesbassyee Bros. Ltd., Trichinopoly, South India
Rodriquez, P. A., Corp. Peruana del Santa, Lima, Peru, South America
Villa, E. A., Lt. Cmdr., Peruvian Navy, Lima, Peru, South America

Total to grade of Associate
United States, Canada, Alaska, and Puerto Rico, 1044
Elsewhere, 19

# OF CURRENT INTEREST

## 1947 Book List Issued for Electrical Engineers

The following list of some important books of interest to electrical engineers has been compiled by the staff of the Engineering Societies Library. The books were selected from those added to the library during 1947. Some equally good books may have been omitted, but the desire for brevity forced the staff to choose rather than to include all.

NATIONAL ELECTRICAL CODE HANDBOOK. By A. L. Abbott. McGraw-Hill Book Company, New York, N. Y., 1947. 633 pages, $4. Dealing with many questions on materials, plans, wiring, and installation, this volume is a practical reference book covering the 1946 National Electrical Code.

FLUORESCENT LIGHTING MANUAL. By C. L. Amick. Second edition. McGraw-Hill Book Company, New York, N. Y., 1947. 318 pages, $4. The principles of operation and the design, construction, and performance characteristics of all types of fluorescent lamps are covered, providing manufacturers, contractors, dealers, and users with a reference manual for solving the various problems of modern fluorescent lighting practice.

ELECTRONIC CONTROL HANDBOOK. By R. R. Batcher and W. Moulic. Caldwell-Clements, Inc., New York, N. Y., 1946. 344 pages, $4.50. Electrical and electronic principles employed in automatic control and regulation services are discussed in detail with emphasis on the versatility of electronic systems.

INVENTIONS AND THEIR MANAGEMENT. By A. F. Berle and L. S. De Camp. Second edition. International Textbook Company, Scranton, Pa., 1947. 742 pages, $6. This comprehensive work presents the principles and practices governing the technical, legal, and business procedures of invention, from the history and theory of the protection of ideas to the methods of exploitation.

THEORY AND APPLICATION OF RADIO-FREQUENCY HEATING. By G. H. Brown and others. Van Nostrand Company, New York, N. Y., 1947. 370 pages, $6.50. Basic principles of radio-frequency heating are presented; applications and illustrations of the principles are given from experimental data, including descriptions of laboratory equipment; deals with the case hardening of steel, the wood-gluing process, solutions to press problems, radio-frequency dehydration, pasteurization, sterilization, and food treatment.

POWER SYSTEM STABILITY. By S. B. Crary. Volume 2. Transient Stability. John Wiley and Sons, New York, N. Y. 1947. 329 pages, $6. Treating the theory of stability and its application to system and apparatus design, this volume discusses in detail such factors affecting transient performance as occurrence, type, and location of short circuits; response of the system to sudden changes in voltage and current; speed of circuit breakers and relays; and response of the excitation systems and governors of the synchronous machines.

SCIENCE AND ENGINEERING OF NUCLEAR POWER. C. Goodman, *editor*. Volume 1. Addison-Wesley Press, Inc., Cambridge, Mass., 1947. 503 pages, $7.50. Covers the basic treatment of nuclear pile design and its practical application, in addition to background material necessary for their understanding; allied subjects such as control, monitoring chemistry of heavy elements, and fission products also are treated. Volume 2 is in preparation.

ELECTRONIC METHODS OF INSPECTION OF METALS. By H. F. Hamburg and others. American Society for Metals, Cleveland, Ohio, 1947. 189 pages, $3.50. Reprinted lectures originally presented at the 1946 National Metal Congress. Electronic methods, direct intensity methods, and supersonic methods are discussed. The DuMont cyclograph, magnetic analysis equipment, and the electron microscope are shown in their applications to metal inspection and testing. The last article describes the application of electronic equipment in the control of steel-making processes.

VERY-HIGH-FREQUENCY TECHNIQUES. Harvard University, Radio Research Laboratory Staff. Two volumes. McGraw-Hill Book Company, New York, N. Y., 1947. 1056 pages, $14. Provides a comprehensive treatment of antennas, direction finding systems, generation of continuous wave power, and reception of signals.

MAGNETIC CONTROL OF INDUSTRIAL MOTORS. By G. W. Heumann. John Wiley and Sons, New York, N. Y., 1947. 589 pages, $7.50. Of interest to engineers concerned with industrial control equipment, this volume provides exhaustive coverage of electric motor performance, characteristics of control devices, and functions of commonly-used control circuits.

ELECTRIC CONTACTS. By R. Holm. Hugo Gebers Förlag, Stockholm, Sweden, 1946. 398 pages. Presents a detailed study of the physical principles of contact phenomena, including all fundamental formulas, with a large amount of tabular and graphic data; the three main parts deal respectively with stationary contacts, sliding contacts, and electric phenomena in switching contacts.

IES LIGHTING HANDBOOK. Paged in sections. Illuminating Engineering Society, 51 Madison Avenue, New York, N. Y., 1947. $7.50. A basic reference handbook designed to provide lighting engineers with the essential information required in their daily work; divided into reference section, application section, appendix, manufacturers' data, and index.

ELECTRONIC TRANSFORMERS AND CIRCUITS. By R. Lee. John Wiley and Sons, New York, N. Y., 1947. 282 pages, $4.50. A reference book on the design of transformers for electronic apparatus; furnishes electronic equipment engineers with an understanding of the effects of transformer characteristics on electronic circuits.

THEORY AND APPLICATION OF MATHIEU FUNCTIONS. By N. W. McLachlan. Oxford University Press, London, England, 1947. 401 pages, $12.50. Addressed to the technologist, the purpose of this volume is to give the theory of Mathieu functions and to demonstrate their application to representative problems in physics and engineering science. These applications are taken from the fields of radio acoustics, mechanics, heat conduction, electromagnetism, and others in which oscillatory effects occur.

WRITING THE TECHNICAL REPORT. By J. R. Nelson. Second edition. McGraw-Hill Book Company, New York, N. Y., 1947. 388 pages, $3. Presents a review of those fundamental considerations which bear on the design and composition of the report, gives specific directions for the setup, outlines a systematic procedure for critical examination, and suggests a series of assignments for those who wish to use the book as a classroom text.

ELEMENTS OF ACOUSTICAL ENGINEERING. By H. F. Olson. Second edition. Van Nostrand Company, New York, N. Y., 1947. 539 pages, $7.50. Presenting the principles and applications of acoustics for the engineer and applied scientist, this volume covers the important new instruments, designs, developments, and present-day practices of acoustical engineering.

GUIDE TO THE LITERATURE OF MATHEMATICS AND PHYSICS INCLUDING RELATED WORKS ON ENGINEERING SCIENCE. N. G. Park, 3d. McGraw-Hill Book Company, New York, N. Y., 1947. 205 pages, $6. Presents a detailed bibliography, containing 1,800 entries, and providing scientists and research engineers with a valuable key to authoritative information, with strong industrial emphasis, on a wide range of subjects; the early part of the book contains a helpful section on reading, reference, and library techniques.

ADVANCED MATHEMATICS FOR ENGINEERS. H. W. Reddick and F. H. Miller. Second edition. John Wiley and Sons, New York, N. Y., 1947. 508 pages, $5. Assuming a knowledge of mathematics through calculus, the authors deal with various special functions, integrals, series and equations, vector analysis, probability, and the operational calculus; problems are presented to emphasize physical application in the main fields of engineering.

ELECTRICAL NETWORK CALCULATIONS. By D. E. Richardson. Van Nostrand Company, New York, N. Y., 1946. 270 pages, $5.75. The purpose of this book is to provide students and practicing engineers with an efficient arithmetic tool for use in securing numerical solutions to electric network problems; tabular methods of solutions are developed for a-c and d-c networks.

ELECTRONIC ENGINEERING PRINCIPLES. By J. D. Ryder. Prentice-Hall, Inc., New York, N. Y., 1947. 397 pages, $6.65. Covers theories of conduction, simple atomic structure, and generalized circuit analysis with linear and nonlinear circuit elements. A basic knowledge of a-c network theory and mathematics through simple differential equations is assumed. The physics involved in emission, space charge, and gaseous conduction phenomena is explained. Theory and applications are grouped closely and applications are chosen mainly from the industrial field.

MECHANICAL MEASUREMENTS BY ELECTRICAL METHODS. By H. C. Roberts. Instruments Publishing Company, Pittsburgh, Pa., 1946. 357 pages, $3. Describes in detail all the methods for electrically measuring displacements, pressure, vibrations, strain, accelerations, and so forth, including the basic principles of the circuits and systems; auxiliary devices such as amplifiers, oscillographs and calibrating devices are dealt with as well as the main equipment.

ELECTROMAGNETISM. By J. C. Slater and N. H. Frank. McGraw-Hill Book Company, New York, N. Y., 1947. 240 pages, $3.50. Originating from the author's "Introduction to Theoretical Physics," this volume contains a more complete treatment of the foundations of electrostatics and magnetostatics and the new developments in the electromagnetic theory.

TECHNOLOGY OF INDUSTRIAL FIRE AND EXPLOSION HAZARDS. By R. C. Smart. Volume 1, 202 pages; volume 2, 184 pages. Chapman and Hall, Ltd., London, England, 1947. 16s each volume. Fire wastage and research are dealt with in volume 1, as well as the thermal reactions of materials and fire risks with agricultural products, coal, industrial fuels, and gases. Hazards with light alloys, light alloy dust explosions, and explosive dusts produced in industry are considered. New materials, techniques, and processes are discussed in volume 2. Dangers due to toxic gases and the use of self-contained breathing apparatus are examined, while electrical fires and explosions due to static electricity and lightning are given close attention. The broad coverage of these two volumes should make them of interest in a wide field of industrial and insurance work.

MODERN ELECTRICAL ENGINEERING MATHEMATICS. By S. A. Stigant. Hutchinson's Scientific and Technical Publications, London, England, 1946. 372 pages, 31s 6d. Outlines some of the progress which has been made in the application of the results of mathematical research to the solution of problems arising in electrical engineering theory and practice. Special reference is made to the theory of symmetrical components applied to the analysis of

unbalanced electric networks and machines. Other modern mathematical methods, such as determinants, matrixes, tensors, are presented and their application indicated.

SEQUENTIAL ANALYSIS. By A. Wald. John Wiley and Sons, New York, N. Y., 1947. 212 pages $4. Gives a full discussion of the new statistical technique known as "sequential probability ratio test"; explains the fundamental theory, the applications, and potentialities of this method of analysis.

PHYSICAL PRINCIPLES OF WAVE GUIDE TRANSMISSION AND ANTENNA SYSTEMS. By W. H. Watson. Oxford University Press, New York, N. Y., 1947. 208 pages $7. The aim of this book is to describe the way in which the technique of handling radio-frequency transmission lines has been extended to deal with propagation through hollow metal pipes known as wave guides; the theoretical and mathematical aspects of the control and transmission of microwaves are emphasized.

## Scientific Research Society Established for Industry

The Scientific Research Society of America, a new national scientific organization designed primarily for industry, has been established with headquarters at Yale University, New Haven, Conn. Articles of Association have been filed with the Secretary of the State in Connecticut, stating that it is a nonprofit corporation devoted to the encouragement and promotion of scientific research. Included among the signers is Professor Edmund W. Sinnott, director of the Sheffield Scientific School and the Yale Division of the Sciences.

The new body is sponsored by, and affiliated with, The Society of the Sigma Xi, a national honorary scientific organization in American universities, which also has its headquarters at Yale University. The new research group has as its primary purpose the organization of chapters in important industrial laboratories where many of the top-flight scientists now are located.

## Communications Association Formed by Armed Forces

According to a recent announcement, with the unification of the Armed Forces now an accomplished fact, the Army Signal Association has been reconstituted as the "Armed Forces Communications Association." Brigadier General David Sarnoff (M '23) will continue as president of the new organization.

Americans engaged in any way in the fields of communication or photography—or interested in them—can contribute toward military preparedness by joining the association whose principal mission is "to ensure that the Armed Forces—Army, Navy, Air Force—shall have communications superior to those of any other nation."

National officers, in addition to General Sarnoff who is president and chairman of the board, Radio Corporation of America, include: Doctor Lee DeForest (F '18) American Television Laboratories, Chicago, Ill.; Carroll O. Bickelhaupt (F '28) vice-president, American Telephone and Telegraph Company, New York, N. Y.; Doctor Frank B. Jewett (HM '45) president, National Academy of Sciences; and Fred R. Lack (M '37) vice-president and director of radio division, Western Electric Company, New York, N. Y.

## Film on "Atomic Physics" Produced by English Company

Some 140 years of history and development of atomic knowledge are covered in a new 10-reel sound motion picture called "Atomic Physics," produced by the J. Arthur Rank Organization, Ltd., in England.

The film is divided into five parts. Part 1, "The Atomic Theory," starts with the theory as proposed by John Dalton in 1801 and outlines the progress made in the 19th century. Faraday's early experiments, Mendeleeff's periodic table, and the ideas then current are illustrated. Part 2, "Rays From Atoms," describes how cathode rays, X rays, and positive rays were investigated. The work of Sir Joseph Thomson is emphasized. Part 3, "The Nuclear Structure of the Atom," reviews the early work of Becquerel and the Curies on radioactivity, and shows how Lord Rutherford's work in this field led to his theory of nuclear structure of the atom.

Part 4, "Atom Smashing: The Discovery of the Neutron," covers the work of the Curies and Sir James Chadwick in connection with the discovery of the neutron. The splitting of the lithium atom by Cockcroft and Walton in 1932 is discussed, and Professor Einstein explains how this work illustrated his theory of the equivalence of mass and energy. Part 5, "Uranium Fission: Atomic Energy," covers the events of recent times leading to the discovery of uranium fission, and the fission process is discussed in some detail. A brief recapitulation of the material covered in the various parts, and some idea of present-day research into the peaceful uses of atomic energy are covered also.

Animated diagrams are used to illustrate important principles. The film is available for purchase or rental through United World Films, Inc., 445 Park Avenue, New York 22, N. Y.

**(Above) Sir Joseph Thomson's cathode-ray tube with which he measured the ratio of charge to mass of the electron. (Below) Aston's first mass spectrometer with which he was able to weigh atoms very accurately and demonstrate the existence of isotopes. These are scenes from "Atomic Physics," a British educational film produced by the J. Arthur Rank Organization and distributed in the United States by United World Films, Inc.**

## Carnegie Institute Receives Japanese Scientific Journals

Several hundred paper-bound journals, representing a major portion of the issues of 12 different Japanese scientific research publications which appeared during World War II, have been received at Carnegie Institute of Technology, and now are being catalogued, according to a recent announcement.

The Carnegie Institute of Technology library is said to be the only one in the United States, except for two government libraries in Washington, D. C., to have in its possession Japanese scientific publications issued since Pearl Harbor. All of the material at the Carnegie Institute of Technology will be available on loan to scientists and students everywhere, upon request.

About one-half of the material is printed in Japanese, the remainder is in English. Translation must be arranged for by the borrower.

The Japanese journals contain material covering the major scientific fields. Numerous articles in the journals indicate the Japanese seem to be up to date in work on vitamins and microbiology, and that they are interested greatly in synthetic polyamides, particularly nylon, on which they have done considerable work. They also are said to have made important contributions in the field of organic chemistry.

A list of the Japanese publications available follows:

1. Abstracts of the *Bulletin* of the Chemical Society of Japan and complete publications.
2. *Transactions*, Society of Mechanical Engineers.
3. *Transactions*, Institute of Metals (expected to be available later on microfilm only).
4. *Journal*, Society of Industrial Chemistry.

5. *Memoirs*, college of engineering and science, Kyoto Imperial University.

6. *Journal*, Mining Institute of Japan.

7. *Journal*, Chemical Society of Japan, and *Abstracts*.

8. Research of the Electrotechnical Laboratory, Tokyo.

9. *Bulletin*, Institute of Physical and Chemical Research, Rikan.

10. Scientific papers of the Institute of Physical and Chemical Research, Rikan.

11. *Transactions*, Mining and Metallurgy Alumni Association, Kyoto Imperial University.

12. *Journal of Iron and Steel Industry of Japan*.

## Oil-Filled Cable System Completed in San Antonio

Installation of one of the few 138,000-volt high-pressure oil-filled cable systems for power transmission in the United States has been completed in San Antonio, Tex., according to a recent announcement of the General Electric Company.

The new system connects San Antonio's municipal steam-turbine power plant to the outlying Olmos and Grandview substations. These two circuits are approximately 7 1/8 and 3 1/4 miles long, respectively, the Olmos line being among the world's longest.

This type of installation consists of three insulated cables contained in an oil-filled 5-inch pipe. The pipe was shipped in 40-foot lengths, which were welded to form an air-tight underground line from the power plant to each of the substations.

The pipe laying progressed by segments of welded pipe up to 1,770 feet long. When such a segment was completed it was pressure-tested for leaks, and dried. Cables then were pulled through by winches, and the section was filled with oil.

The line used for pulling the cable through the pipe was blown through by an air compressor unit which enabled the pulling of cable into continuous lengths of pipe up to one-third of a mile long.

The complete San Antonio line was filled with insulating oil and held at a nominal pressure of 200 pounds per square inch by a permanent pumping unit installed at the power plant ends of the two lines.

## Faster Astronomical Plates for 200-Inch Telescope

Special photographic plates made by Eastman Kodak Company, Rochester, N. Y., which will be used in the 200-inch Palomar telescope, have emulsions that are four times "faster" than those on astronomical plates in 1928, the year the big telescope project was begun. This increased speed, or sensitivity to light, is the result of continuous studies to improve photographic emulsions during those years.

These faster emulsions today mean that the 200-inch telescope, which is really the biggest camera in the world, will be able to "see" just that much farther into the universe. Because of the wide range of sensitivities in emulsions now available, the plates are not stocked generally, but are made to order for astronomers and other scientists in an experimental department of the Kodak laboratories. Some of the plates for general astronomical use, for example, are supersensitive to red and infrared light. Others, for photographing certain types of stars, are more sensitive to blue, and others react to yellow-green light. In many instances, a spectroscope is attached to the telescope and the resulting spectrographs on the plates tell astronomers about the constitution and motion of the stars. Salient features of the telescope and its associated control apparatus were described in an article called "Electrical Features of the 200-Inch Telescope," by Bruce H. Rule (A '36) which appeared in *ELECTRICAL ENGINEERING* a number of years ago (*EE, Feb '42, pp 67–78*).

**B. G. Tremaine Dies.** Burton Gad Tremaine, pioneer in the electric lighting field, died at his home in Cleveland, Ohio, on February 16, 1948, at the age of 84. Together with the late F. S. Terry he founded Nela Park, the headquarters and laboratories of the General Electric lamp works, in East Cleveland, Ohio, on April 18, 1913. He was active in the affairs of the General Electric Company for 35 years, and was a director of the company for more than 20 years. He was also an honorary vice-president of the company.

## New Metal Lens for Microwaves Developed at Bell Laboratories

An entirely new type of metal lens for focussing radio waves in radio relay systems is under development at Bell Telephone Laboratories, New York, N. Y. Present plans call for the use of the lens, theoretically capable of handling from 50 to 100 television channels or tens of thousands of simultaneous telephone messages, in the proposed radio relay link which the Bell System is planning between New York and Chicago. The new lenses are based on the theories of light transmission through atomic and molecular structures and use metallic spheres, disks, or strips in a scaled-up pattern similar to the arrangement of atoms in a crystalline molecule.

The new artificial "metallic dielectrics" reproduce, on a much larger scale, the atomic or molecular processes occurring in an ordinary dielectric. The free electrons in the metallic elements flow back and forth under the action of the alternating radio field and cause the elements to become oscillating dipoles similar to the oscillating molecular dipoles of the dielectric. The array thus exhibits "polarization," a property of materials closely related to their refractive or focussing power.

As the array of conducting elements refracts or bends radio waves, it can be formed into a lens for focussing microwaves. The only requirement on the elements is that their spacing and size be small relative to the wave length. When the spacings of a lattice become larger than the wave length, the waves become diffracted and, instead of the desired result, namely a single sharp beam, a diffraction pattern results. The energy then is scattered in many directions, as in X-ray diffraction patterns where the wave length is short as compared with the crystal lattice spacings.

The older lenses employ thin metal plates which act as wave guides and achieve their focussing effect by virtue of the higher velocity of radio waves passing between the plates. The refractive power of these lenses depends on the length of the radio waves passing through them; thus waves of different wave lengths do not have the same focal point with lenses of this type. This fact limits the band of wave lengths over which such lenses will operate satisfactorily. In the new lenses, however, the waves are slowed down as are light waves in an ordinary glass lens and all wave lengths are slowed down the same amount. As a result these lenses can handle radio waves over a considerable bandwidth.

**Doctor Winston E. Kock with three small-scale models of the new metal lens, which he developed. The model in the rear uses metallic spheres mounted on insulators; that to the right, metallic disks, also mounted on insulators; that in the foreground, thin metallic disks mounted in polystyrene foam**

## MIT Receives Atomic Research Grant

A $250,000 grant for atomic research and training of nuclear scientists has been made to the Massachusetts Institute of Technology, Cambridge, Mass., by The Texas Company. The funds will be used for long-range pure research in nuclear fission and related basic studies on the ultimate nature of matter and energy, to construct high-voltage equipment of advanced design, and to train scientists in nuclear theory and its application. This work will be carried on primarily in the laboratory for nuclear science and engineering, which will co-ordinate its efforts with the departments of physics, chemistry, chemical, electrical and mechanical engineering, metallurgy, and biology, for maximum interchange of information.

Investigations already under way in the laboratory have revealed that cosmic rays, nature's source of particles of highest energy, are composed of less than one per cent free electrons, contrary to former scientific belief. The newly-acquired knowledge that cosmic rays are principally protons is another fact in the unexplored field of nucleonics which may lead to vast practical applications.

The tools which will be used in this project include the institute's cyclotron and two electrostatic generators with capacities up to 4,000,000 volts which are already in operation. Future developments call for still larger instruments, including a 300-million-electron-volt synchrotron, now in the process of construction, and a 12-million-volt electrostatic generator.

One division of the investigation will concentrate on studies of nuclear theory, nuclear chemistry, and other problems bearing on a better understanding of nuclear structures and forces, and of the fission process and its products.

## Microwave Astronomy at Cornell University

A microwave or radio telescope that will measure radio "signals" given off by the "milky way" and the sun has been designed and built by members of Cornell University's engineering staff. It is being assembled five miles from Ithaca—near the East Hill airport—at a site free from man-made electrical noise which might interfere with the reception of the very weak radio impulses arriving from outside the earth.

The apparatus is designed to play a major role in the new field of radio astronomy, according to Doctor Edwin W. Hamlin, director of the project. It is believed that astronomical measurements made at short-wave and microwave frequencies will add greatly to knowledge of the structure of the universe. The sun, a prolific generator of radio waves, will be studied in detail.

The Cornell microwave telescope, weighing about eight tons and designed to operate in winds as high as 60 miles per hour, will be operated outdoors by means of remote controls. A large radio antenna replaces the usual lens and mirror system of an optical telescope. The antenna will be used to collect the electromagnetic wave radiations approaching at radio frequencies from outer space for amplification and measurement. As the earth's atmosphere is very nearly transparent to many radio waves, observations will proceed around the clock, regardless of most weather conditions which would prevent optical measurements. The project is sponsored jointly by Cornell University and the Office of Naval Research.

## New Dam Projected for Pacific Northwest

Plans are now in progress, under auspices of the Bureau of Reclamation, for the construction of Hungry Horse Dam, fourth largest concrete dam in the world, on the south fork of the Flathead River, nine miles southeast of Columbia Falls, Mont. When completed, Hungry Horse Dam will provide much-needed power production for the Pacific Northwest, flood control, irrigation water for Western Montana lands, and stream regulation for the Columbia River which will increase firm power capacities of existing Columbia River plants. Construction of the dam will create a reservoir with a capacity of 3.5 million acre-feet of water. Partial storage is planned in the reservoir by 1952 to catch the annual spring runoff.

Specifications provide for the construction of a concrete arch dam 520 feet above foundation, 2,115 feet long, with an arch radius of 1,200 feet. Approximately 3 million cubic yards of concrete will be required for the dam and appurtenant structures. A feature of the project will be a glory-hole spillway with a tunnel 24.5 feet in diameter which will pass a flow of 53,000 cubic feet per second. A 30-foot-wide roadway is to be constructed across the crest of the dam.

Also to be constructed is a reinforced concrete power plant at the downstream toe of the dam in the river channel. The plant will house four 75,000-kva generators. Power produced at Hungry Horse Dam will be integrated with the Bonneville and Grand Coulee systems and other plants of the Northwest power pool.

# HONORS • • • • • •

## General Electric Announces Charles A. Coffin Awards

Fifty-eight employees of the General Electric Company and its manufacturing affiliates, who performed work of outstanding merit during the years 1946 and 1947, have been presented Charles A. Coffin awards for their accomplishments. Named for the first president and one of the founders of the company, the Charles A. Coffin awards, the company's highest, carry a certificate and a cash honorarium. In the present awards, the company divided $114,500, or $1,250 per person, among those cited.

The awards provide recognition by the company of accomplishments of unusual merit by emplyees engaged in all types of work. Involved in the 58 awards are 45 separate accomplishments, some of the awards being to several persons engaged in the same activity. Of the awards, 54 went to General Electric employees and four to employees of affiliates, which were eligible for the awards for the first time. Awards granted for 1946 and 1947 bring to 779 the number of individual Coffin awards presented by the company since the program was inaugurated in 1923.

Work recognized by presentation of the awards was in the fields of electronic tubes and circuits, improved product design, silicone rubber applications, turbosupercharger production, instrument development, packaging methods, toolmaking, gun-control equipment, measuring devices, and many others.

Among the winners this year are six men who were recipients in past years. According to the types of work in which the new honorees were engaged, 36 were design and laboratory engineers, 7 were workmen, 5 were manufacturing supervisors, 5 were tool designers or draftsmen, and 5 were sales, application, and field engineers.

Selection of the award winners is made after careful study by the company's advisory committee, on the basis of initiative, perseverance, courage, and foresight. Candidates are recommended by their superiors and screened by department review committees before their names are submitted for final screening. Those finally selected are honored because of accomplishments beyond what normally is expected of them in their work. A major factor is the comparison of the achievement with the opportunity or lack of opportunity of the employees to distinguish themselves with creative or constructive enterprises in the course of their daily work. Records show that many Coffin Award winners of past years have risen to executive positions in the company.

## Jewett Fellowships Awarded for 1948-49

Nine scientists have been named by the American Telephone and Telegraph Company to receive the 1948–49 Frank B. Jewett fellowships for research in the physical sciences. The awards grant $3,000 to the recipient, and $1,500 to the institution at which he chooses to do his research. Three of the winners are mathematicians, three are chemists, two are physicists, and one is an astronomer.

Grants for the fellowships were established four years ago by the American Telephone and Telegraph Company, upon the retirement of Doctor Jewett, vice-president in charge of development and research. The purpose is to stimulate

and assist research in the fundamental physical sciences and particularly to provide the holders with opportunities for individual growth and development as creative scientists.

The fellowships are awarded on recommendation of the Frank B. Jewett Fellowship Committee, consisting of seven members of the technical staff of Bell Telephone Laboratories who are actively and creatively engaged in research in physics, mathematics, and chemistry. Primary criteria are: demonstrated research ability of the applicant, the fundamental importance of the problem he proposed to attack, and the likelihood of his growth as a scientist. The awards are designedly postdoctorate and only scientists who recently have received their doctorates or who are about to receive them normally are considered.

## Industrial Research Medal Awarded to Games Slayter

Games Slayter, vice-president in charge of research and development, Owens-Corning Fiberglas Corporation, has been awarded the 1948 Industrial Research Institute medal. Mr. Slayter was honored for "his outstanding contribution to the field of industrial research through his leadership in the development of glass fibers and their commercial application."

Award of the medal was made at the winter meeting of the Industrial Research Institute, Inc., which was held February 4–6, 1948, in Rye, N. Y. Topics covered at the meeting sessions included: government and university relationships to industrial research; problems growing out of scientific research sponsored and supported by industry in educational and nonprofit research institutions; an analysis of the recent reports on science and public policy by the President's Scientific Research Board, with special reference to the implications for industrial research; and a discussion of some of the factors which control in research work and in utilization of the products of nuclear science.

The publication of a comprehensive monograph on the organization and management of research in industry was announced at the business meeting. The book was edited by C. C. Furnas of Cornell Aeronautical Laboratories, and published by D. Van Nostrand Company, New York, N. Y.

## 1948 Mascart Medal Goes to Doctor Langmuir

Doctor Irving Langmuir, associate director of the General Electric Company's research laboratory, Schenectady, N. Y., has been chosen 1948 recipient of the Mascart Medal, triennial award of the Société Française des Electriciens. Doctor Langmuir was nominated as candidate for this award by the AIEE.

The triennial Mascart Medal was created in 1923 by the French society in memory of Mascart, eminent scientist and founder of the Société Française des Electriciens, the Central Laboratory, and the École Superieure d'Electricité. It is awarded to a scholar or an engineer, French or foreign, for his work in pure or applied electricity.

## NBS Scientists Receive Reed Award

Two National Bureau of Standards scientists, Doctor Galen B. Schubauer and Doctor Harold K. Skramstad, received the Sylvanus Albert Reed Award on January 26, 1948, at the annual meeting of the Institute of Aeronautical Sciences in New York, N. Y. The award is made each year for "a notable contribution to the aeronautical sciences resulting from experimental or theoretical investigations, the beneficial influence of which on the development of practical aeronautics is apparent."

Doctors Schubauer and Skramstad were cited for "their contributions to the understanding of the mechanism of transition from laminar to turbulent flow." This transition occurs in a boundary layer, which is a skin of air set in motion by friction on any surface moving through the air, such as that of an airplane in flight. The turbulence that develops in this layer is a major factor that must be considered in the design of airfoils and is of particular significance in the design of aircraft of low drag.

Doctor Schubauer is chief of the aerodynamics section of the Bureau of Standards, and Doctor Skramstad is chief of the bureau's guided missiles section.

## Harlow S. Person Honored for Scientific Management

Doctor Harlow S. Person, consultant in business economics and management, and internationally recognized for his pioneering in the field of scientific management, has been awarded the gold medal of the Comité International de l'Organisation Scientifique (International Committee of Scientific Management). The medal was conferred by the National Management Council.

Doctor Person was cited for the medal, one of the outstanding honors in the management field, at the eighth International Management Congress held in Stockholm, Sweden, last July. The citation reads in part:

Doctor Harlow Stafford Person, dean of the first business school to teach scientific management; distinguished managing director of the Taylor Society, and editor of its epoch-making bulletin; as practitioner made unique applications of scientific management to government operations, national and international; widely recognized expositor of a philosophy of management squared with modern economics and tenable in a moral world.

# OTHER SOCIETIES

## 1948 NACE Conference to Meet in St. Louis

The 1948 Conference and Exhibition sponsored by the National Association of Corrosion Engineers will be held April 5–8, 1948, at the Hotel Jefferson, St. Louis, Mo. The 4-day session will include an extensive technical program, as well as an All-Corrosion Exhibition.

The technical program will consist of ten symposiums at which approximately 40 papers on corrosion, its causes, and methods for combating it, will be presented by corrosion authorities. The symposiums will include: oil industry, water industry, chemical industry, electrical industry, cathodic protection, protective coatings for metals, general industry, communications, salt water corrosion, and the gas industry. A general discussion will follow each of the meetings.

At the All-Corrosion Exhibition, various manufacturers will present displays of the latest materials, methods, and equipment for combating corrosion.

**SMPE to Meet.** The Society of Motion Picture Engineers will hold its 63d semi-annual convention in Los Angeles, Calif., from May 17 to May 21 inclusive, according to a recent announcement. More than 2,500 technical experts are expected to attend from the motion picture industry, the film and sound equipment manufacturers, scientific foundations, and experimental laboratories. The convention will get under way on the morning of May 17, with a get-together luncheon scheduled for noon of that day. Remainder of the five days will be devoted to business and technical sessions in the mornings, afternoons and evenings, except for May 19 when a cocktail party and dinner dance will be given for members and guests at the Santa Monica Ambassador Hotel, Santa Monica.

## Heating Engineers Will Study Panel Heating System Control

A comprehensive investigation on the control of panel heating and cooling systems has been approved by the American Society of Heating and Ventilating Engineers Committee on Research. This action of the committee activates the third phase of the over-all research program on panel heating and cooling. The committee previously approved projects involving heat transfer within and behind the panel and heat transfer between the panel surface and the space.

The investigation, to determine what controls are necessary for comfort regulation of panel heating and cooling systems, will include field surveys and tests in

## Future Meetings of Other Societies

**American Iron and Steel Institute** May 26–27, 1948, New York, N. Y.

**American Society for Engineering Education.** June 14–18, 1948, Austin, Tex.

**American Society for Testing Materials.** Annual meeting, June 21–25, 1948, Detroit, Mich.

**American Society of Agricultural Engineers.** Annual meeting, June 20–23, 1948, Portland, Oreg.

**American Society of Civil Engineers.** Spring meeting, April 7–9, 1948, Pittsburgh, Pa.; summer convention, July 21–23, 1948, Seattle, Wash.

**American Society of Lubrication Engineers.** April 19–21, 1948, Buffalo, N. Y.

**Canadian Institute of Radio Engineers.** Convention, April 30–May 1, 1948, Toronto, Ontario, Canada.

**CIGRE (International Conference on Large Electric High-Tension Systems).** Biennial meeting June 24–July 3, 1948, Paris, France.

**Edison Electric Institute.** Annual engineering meetings, May 3–5, 1948, Chicago, Ill.; annual convention, June 2–4, 1948, Atlantic City, N. J.

**Midwest Power Conference.** Annual meeting sponsored by Illinois Institute of Technology, April 7–9, 1948, Chicago, Ill.

**National Academy of Sciences.** April 26–28, 1948, Washington, D. C.

**National Association of Broadcasters.** 26th annual convention, week of May 17, 1948, Los Angeles, Calif.

**National Association of Corrosion Engineers.** Fourth annual conference and exhibition, April 5–8, 1948, St. Louis, Mo.

**National District Heating Association.** 39th annual meeting, May 18–21, 1948, St. Louis, Mo.

**National Electrical Wholesalers Association.** 39th annual convention, May 2–7, 1948, Buffalo, N. Y.

**Pittsburgh International Conference on Surface Reactions.** June 7–11, 1948, Pittsburgh, Pa.

**Southern Machinery and Metals Exposition.** Third exposition, April 5–8, 1948, Atlanta, Ga.

various types of buildings, with analytical investigations undertaken concurrently. Experimental studies are to include hot water, warm air, and electricity as heating media. These investigations will involve various combinations of heavy and light panels and heavy and light building construction with both large and small glass areas. Control procedure will include "on-off" and "continuous operation" with inside and outside thermostats used singly and in combination. Night set-back and other operational details as may prove to be desirable also will be studied.

## New Orleans Is Host to ASME Spring Meeting

The 1948 spring meeting of The American Society of Mechanical Engineers was held March 1–4, 1948, in New Orleans, La. Several hundred members of the society attended the 4-day round of technical and general sessions.

Nuclear energy was the theme of the luncheon program opening the meeting on March 1, and some eight technical sessions were held during the meeting, with 25 speakers from various industries presenting papers on gas turbines, metals engineering, power, materials handling, heat transfer, fuels and processing, and management. Inspection trips included a tour of the new steam-electric generating station of the New Orleans Public Service, Inc., located on the Industrial Canal; and the American Sugar Refinery, where visitors witnessed the unloading of raw sugar, and its refining, processing, and packaging.

The decision to hold the spring meeting of the ASME in a southern city for the third successive year was made by the society in recognition of the growing industrial importance of the South. In 1946 the meeting was held in Chattanooga, Tenn., and in 1947 in Tulsa, Okla.

## ASEE to Meet in Texas in June

It may be of some special interest and concern to AIEE members who also are members of the American Society for Engineering Education, to note that the regular annual ASEE convention is scheduled to be held in Austin, Tex., the week of June 14, immediately preceding the week of the AIEE summer general meeting in Mexico City.

With these two meetings located as they are, it will be relatively convenient for persons interested in both of them to attend both on the same trip with very little extra time or traveling involved.

## ASTM Annual Meeting to Be Held in Detroit

The 1948 annual meeting of the American Society for Testing Materials, the 51st such session of this national technical organization, is to be held in Detroit, Mich., the week beginning June 21. During this week there will be some 20 technical sessions, with a large number of technical papers and reports in the field of materials. There will be more than 300 meetings of the society's technical committees, concentrating their work on standards and research in materials. Throughout the week of the meeting the society's eighth Exhibit of Testing Apparatus and Related Equipment will be in progress.

One of the features of the meeting will be the 1948 Edgar Marburg Lecture to be delivered by Doctor Paul Aebersold, chief of the isotopes division, Atomic Energy Commission, Oak Ridge, Tenn. He is expected to discuss the industrial applications of these materials which have such phenomenal prospects for industry and for mankind.

Displays of testing apparatus and laboratory supplies, all of which are important in evaluating and testing materials and products, will be exhibited during the 1948 ASTM Apparatus Exhibit at the headquarters hotel, the Book-Cadillac. Every two years the society sponsors an exhibit, in which there are not only displays by companies in the apparatus industry, but also special research and educational displays sponsored by the society's committees, research institutes, and so forth. This exhibit will provide an opportunity to review the progress that is being made in this field.

**ACS Meeting Planned.** Better fuels from petroleum, recent advances in food technology, and safer methods of handling deadly radioactive materials are among the subjects to be discussed at the 113th national meeting of the American Chemical Society, in Chicago, Ill., April 19–23, 1948. Several hundred technical papers reporting progress in the fields of textiles, rubber, insecticides, soap, sugar, vitamins, drugs, and virtually every other branch of chemical science will be presented at meetings to be sponsored by 17 professional divisions of the society; 125 local sections of the society will be represented.

# EDUCATION • • •

## Graduate Mathematics Degree Offered by Brooklyn School

In a further emphasis upon the fundamental concepts in engineering education, the Polytechnic Institute of Brooklyn will offer the new degree of master of science in applied mathematics to meet the growing need for men with a knowledge of mathematics which can be applied broadly in all fields of engineering. Prior to the war, only a limited number of engineers availed themselves of the Polytechnic graduate course in mathematics, but the broader applications of basic sciences stimulated by wartime developments very substantially have increased the number of men enrolled in these courses today and have brought a demand for a graduate degree in the field.

Among the special fields of applied mathematics in which the institute will offer elective courses in the curriculum are mechanics, mathematical physics, physical chemistry, electrodynamics, and mechanical vibrations.

## Harvard Offers Degree of Master of Engineering

A new program to provide research training and experience for engineers headed for careers in industry and government has been instituted at Harvard University's graduate school of engineering according to a recent announcement.

The new course will require two years of study beyond the bachelor's degree

and will lead to a master of engineering degree. Offered for the first time in the fall of 1948, the new master's degree is designed as a terminal degree for those men who desire research experience, but want to start their engineering careers without going on to the 3-year doctoral degree.

## JOINT ACTIVITIES

### W. C. White Chosen NEC Board Chairman

The National Electronics Conference, Inc., which will hold its annual technical forum at the Edgewater Beach Hotel, Chicago, Ill., November 4–6, 1948, has selected W. C. White (M '46) General Electric Company, Schenectady, N. Y., as chairman of the board of directors for the current year.

A program of approximately 50 technical papers covering all phases of electronics, together with exhibits of manufacturers' new electronic equipment, is being planned. Larger space facilities than in former years will be available, both for exhibits and meetings. The entire program is under the joint sponsorship of the Illinois Institute of Technology, Northwestern University, the AIEE, Institute of Radio Engineers, and the University of Illinois. Manufacturers interested in acquiring exhibit space at this conference should write to J. A. M. Lyon, Northwestern Technological Institute, Evanston, Ill.

Other officers elected for the coming year in connection with this national forum on electronic research, development, and application were:

*President:* E. O. Neubauer (M '44), Illinois Bell Telephone Company

*Executive vice-president:* G. H. Fett (M '38), University of Illinois

*Secretary:* R. R. Buss (A '40), Northwestern Technological Institute

*Treasurer:* O. D. Westerberg, Commonwealth Edison Company

*Vice-president in charge of arrangements:* Karl Kramer, Jensen Manufacturing Company

*Vice-president in charge of program:* H. A. Leedy (M '46), Armour Research Foundation

*Vice-president in charge of publicity:* L. G. Killian, Cook Research Laboratories

*Vice-president in charge of publication:* A. H. Wing (M '41), Northwestern Technological Institute

*Chairman of exhibits committee:* J. A. M. Lyon (A '38), Northwestern Technological Institute

*Chairman of hotels committee:* R. K. Metcalf (A '46), Illinois Bell Telephone Company

long as atomic power is secured by the methods of development now under discussion in the technical press.

The location of wind turbines in the neighborhood of the load centers, eliminating most of 300 to 500-mile transmissions, is a weighty advantage, as is their strong stabilizing effect in electrical operations.

The inherent simplicity of the aerogenerator is conspicuous, not only the free delivery of the wind and the absence of auxiliaries, but the structural and operational simplicity as well.

While wind turbine sites should be selected with great discrimination, as an auxiliary in an existing system, wind energy practically is unlimited.

In adding wind power units near load centers, apparently no interstate agreements are necessary.

In view of this favorable showing for wind energy, the writer suggests that it be included in the power studies for this region, so that ample time may be available for an orderly development of the new type of power.

It may be added that the southwestern states do not offer the only opportunity for the favorable use of wind energy.

PERCY H. THOMAS (F '12)

(Office of the Chief Engineer, Federal Power Commission, Washington, D. C.)

# LETTERS TO THE EDITOR

**INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.**

### Southwest Power Shortage

*To the Editor:*

In *ELECTRICAL ENGINEERING* for December 1947 (*pp 1184–93*), is found a comprehensive study of multipurpose water potentialities in the Southwest states, entitled, "The Proposed Colorado River Developments." The salient statement of that article from the writer's present point of view is the conclusion that the natural growth of power demand in this region tributary to Los Angeles will exceed all undeveloped available power in the lower Colorado River Basin within 15 years. With this prospect should be considered the fact that California now has had to go East for natural gas. In view of this indication of a serious shortage of electric power in the by no means distant future, the suggestion is made that the energy in the wind be considered as a supplementary source of power.

In such a system as that correlated with the Colorado River plants, in which hydro storage is or will be practically unlimited from the point of view of the vagaries of the wind, the firming of wind power obtained by drawing on reservoir storage becomes a matter merely of providing necessary hydro generating capacity at the proper points in the system. Such capacity is necessary only so far as idle capacity does not exist already during the dry times, somewhere in the system. The superposition of the relatively very short cycle of wind energy variations on the much longer water cycles will leave the effectiveness of the hydro storage as such practically unchanged.

Very materially reducing this dependence on storage is the natural diversity in the wind between well separated aerogenerator sites in a state-wide system.

If the writer's survey of the availability of wind energy for electric power be taken as a guide, this source, as an auxiliary to steam and hydro, will have a cost well below that of power from any other source,* even from atomic energy, as long as atomic power is secured by the methods of development now under discussion in the technical press.

The location of wind turbines in the neighborhood of the load centers, eliminating most of 300 to 500-mile transmissions, is a weighty advantage, as is their strong stabilizing effect in electrical operations.

The inherent simplicity of the aerogenerator is conspicuous, not only the free delivery of the wind and the absence of auxiliaries, but the structural and operational simplicity as well.

While wind turbine sites should be selected with great discrimination, as an auxiliary in an existing system, wind energy practically is unlimited.

In adding wind power units near load centers, apparently no interstate agreements are necessary.

In view of this favorable showing for wind energy, the writer suggests that it be included in the power studies for this region, so that ample time may be available for an orderly development of the new type of power.

It may be added that the southwestern states do not offer the only opportunity for the favorable use of wind energy.

PERCY H. THOMAS (F '12)

(Office of the Chief Engineer, Federal Power Commission, Washington, D. C.)

* See monographs by Percy H. Thomas, issued by the Federal Power Commission, "Electric Power from the Wind" and the "Wind Power Aerogenerator."

### Voltage Notation Conventions

*To the Editor:*

In the article, "Voltage Notation Conventions," by Myril B. Reed and W. A. Lewis, which appeared in a recent issue of *ELECTRICAL ENGINEERING* (*EE, JAN '48, pp 41–8*), the authors have summarized current practice in the use of single and double subscript notation to indicate assumed positive directions of voltages and currents. I believe that they have not substantiated their conclusion that the differentiation between voltage rises and voltage drops need not be maintained, which is implied in the statement that the order of the subscript always should be the same, "regardless of whether the voltage is considered as generated or consumed."

The authors have not considered entirely the teaching of the elements of the electric circuit when they decline to differentiate between voltage rises and voltage drops. For example, in their Figure 2*B* they would propose that the potential difference between *a* and *b* should be given as $V_{ab}$ which, in this generator, gives rise to a current $I_{ba}$. Now how much harder that is to permit a student to get a mental picture of a voltage $V_{ba}$ and a current $I_{ba}$ than if we talk about the voltage rise $E_{ba}$ and the current $I_{ba}$. Again, when the 2-winding transformer of Figure 7 of the article is to be studied for the first time the student recalls the formulated statement of Lenz's law and thinks of convention 11*A* of the appendix of the article, where the minus sign is used. To build on this foundation

the natural approach is to show the vector representing the induced electromotive force as lagging the exciting current by 90 degrees. This is just 180 degrees out of phase with the vector $V_e$ shown in the article's Figure 7. It allows the instructor then to build up the vector diagram of the secondary circuit with the argument that the induced electromotive force in the secondary will be in time phase with that in the primary as it is the same mutual flux which is inducing both voltages.

In the same appendix, the authors point out that the currents in the primary and secondary of the transformer of Figure 7 are shown nearly in phase on the vector diagram, "although considered to be opposed magnetically in the windings." It seems quite apparent that it would be simpler from the viewpoint of the student to show the phase opposition of the *effects* of the currents by allowing currents themselves to be represented as being in phase opposition. If the student is to draw magnetomotive forces on this vector diagram, he must remember to draw the magnetomotive force of the primary current or the secondary current 180 degrees out of phase with its appropriate current. Surely to show the currents in phase opposition is much more illuminating than the drawing of magnetmotive force in opposition to the current producing them.

In conclusion, while the authors' summary is valuable because it draws attention to what is being done in the educational field, the conclusions as to which method is preferred do not appear warranted.

G. H. FETT (M '38)

(Associate professor of electrical engineering, University of Illinois, Urbana, Ill.)

*To the Editor:*

By no means the least headache of engineering education, especially in the early stages, is the rational understanding of those elemental tools of the trade, units and symbols. This fact need not be labored here. Of these two, symbols is possibly more formidable than units because the former more fully eludes the benefits of standardization.

Even where standardization has minimized the scope of variation, it is yet to be noted that the practices of industry develop more from the influence of an economy of convenience than from the rigor of academic logic. This is as it should be, but does tax the ingenuity of the teacher to develop engineering as a rational treatment of fundamentals; "rational," that is, within the sensible limits of campus facilities; it also contributes its small share to the debate of such issues as the sign for reactive power, recently active in the Institute.

I am impressed that the authors of "Voltage Notations Conventions" have done a service for us which too long has been neglected. We have encountered, even as no doubt have the authors, numerous concepts other than they describe regarding the significance of subscripts for alternating voltage and current. Some textbook authors even have used other "scripts" than "sub" with little regard for industrial practices or practicality.

The authors, I believe, have focussed attention rather well on the prevailing status of subscript practice. Because the report advocates adoption of the concepts expressed in my text, among others, any remarks I might make favoring it are at some disadvantage as possibly biased. This I would risk balancing against the significance of an extensive period of study, discussion, and experience with the subject before ever going into print with it in 1943.

As indicated by the authors, the confusion is largely about voltage, the erroneous ascribing of the property of direction to voltage, and some insistance on an unnecessary degree of distinction between the voltage or electromotive force of a source and the voltage of a load. Regarding irection, it is worth observing that Ohm was motivated considerably in his study of the galvanic circuit by the work of Fourier on heat. He sensed an analogy between the laws for flow of heat and of electricity which still has merit; the hot and cold of temperature is quite comparable to the positive and negative of voltage, electromotive force, or electric potential. Because some pioneer did not happen to conjure up any concept that a heat source might have "thermomotive force" to push heat around like a mechanical force does mechanical masses, we today do not talk or think about the "direction" of temperature or counter-temperatures, and so forth. We seem to get along very nicely without these concepts in the thermal field; and I am quite sure that they in truth have and do make no more contribution to the understanding of electrical than they might have made to thermal technology. As it is, we are prone today to state that between two points there can be but one voltage or potential difference and then proceed to confuse a given problem by substituting for this simple concept a profusion of quite unnecessary man-made trouble about electromotive force, directions, counter-electromotive force, and the like. which must amuse Mother Nature no end. It seems not always to be the professor who may be represented as "making a simple concept seem complicated"; I find my industrial friends are mostly quite as proficient in voltage directionology as any one else.

I am inclined to introduce vectors and vector notation to my students as closely associated with or deriving from oscillograms and their notation. Live oscillographs are obtained readily directly from the live circuit, but vector diagrams are mostly man-made, and when divorced from their related oscillograms, are quite exposed to human violence. It seems helpful to tag an oscillogram with a label like $e_{ab}$, $v_{ab}$, or $i_{ab}$ in the same sense as we would tag a vector $E_{ab}$, $V_{ab}$, or $I_{ab}$ and never allow the vector completely to eclipse the oscillogram in our thinking about electric circuits.

Regarding the use of labels at the ends of a vector, it is to be noted that this notation can be applied safely only to voltage and not to current. It seems to me that for this reason at least it is best discarded in favor of a notation equally applicable to both voltage and current.

There is considerable merit in the single subscript notation, especially where the subscript connotes the functional identity of the circuit quantity like $I_R$ (current through resistance $R$), $E_\phi$ (electromotive force induced by flux $\phi$) and so forth. With the precautions indicated by the authors it is as foolproof as the double-subscript notation. For the present, students should be taught both notations.

I favor the authors' suggestion that a sign of positive polarity be marked on the circuit for each voltage because the arrow is misused too easily. It should be cautioned, however obvious, that the polarity sign must not merely label a *point* on the circuit, but must be so positioned as to leave no doubt where in the circuit the associated negative point is located for the particular voltage. Note, as in the authors' Figure 3, no sign is associated with a lettered point like $b$ but with voltage $E_b$ and with $E_b$ separately.

I am delighted to note that the "Summary and Recommendations" of the authors is directed to the AIEE Standards committee. Editorially may I suggest that item 5 be modified to substitute for "generated or consumed," "a source or load quantity"—voltage, of course, cannot be consumed, although there is ample precedent for the usage of the authors. Perhaps in item 6 it is well to insert "instantaneous" to modify "value" or "voltage."

In reference to Appendix I of the article, I heartily would emphasize attention to the reasoning by which the primary and secondary vectors both of voltage and current are on the *same* side of the vector diagram. Especially in view of the practice of frequently reducing the transformer to an equivalent circuit diagram (as in the authors' Figure 7) it is nonsensical to pursue the "butterfly" diagram inflicted on the profession since the pioneering days of vector diagramming.

E. M. STRONG (M '40)

(Professor of electrical engineering, Cornell University, Ithaca, N. Y.)

## NEW BOOKS . . .

**The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.**

CIRCUITS AND MACHINES IN ELECTRICAL ENGINEERING. Volume 1, CIRCUITS. 367 pages. Volume 2, MACHINES. 370 pages. By J. O. Krachenbuehl, M. A. Faucett. Second edition. John Wiley and Sons, New York, N. Y.; Chapman and Hall, London, England, 1947. Illustrations.

diagrams, charts, tables, 9¼ by 6 inches, cloth, $4.25 each volume. Written primarily for nonelectrical engineering students, this volume also may be used as a first course for those who are starting in the electrical engineering field. This second edition represents a revision and an expansion of the original book. Now presented in two volumes, one deals with circuits, the other with machines. Additional material on electronics has been added, as well as data on transformers. The material on machines has been revised greatly. Features of this book are a unified treatment of alternating and direct current, a wealth of illustrative figures, and new problems.

ELECTRONIC METHODS OF INSPECTION OF METALS. By H. F. Hamburg and others. American Society for Metals, 7301 Euclid Avenue, Cleveland, Ohio, 1947. 189 pages, illustrations, diagrams, charts, tables, 9¼ by 6 inches, cloth, $3.50. Seven uses for electronics in the inspection of metals are described in these reprinted lectures originally presented to the members of the American Society for Metals during the 1946 National Metal Congress. Electronic methods, direct intensity methods, and supersonic methods are discussed. The DuMont cyclograph, magnetic analysis equipment, and the electron microscope are shown in their applications to metal inspection and testing. The last article describes the application of electronic equipment in the control of steelmaking processes.

ELEMENTARY NUCLEAR THEORY. By H. A. Bethe. John Wiley and Sons, New York, N. Y.; Chapman and Hall, London, England, 1947. 147 pages, diagrams, charts, tables, 8¼ by 5½ inches cloth, $2.50. As the volume contains only selected topics in the theory of atomic nuclei, it is not intended as a text for the entire theory, but rather an introduction for students and scientists who are not specialists in the study of nuclear physics. Emphasis is placed on the problem of nuclear forces, and the treatment is entirely from the empirical point of view. The available evidence on nuclear forces is presented from the behavior of the simplest nuclear systems. Purely theoretical considerations, such as the meson theory, are treated briefly. The theories of beta disintegration and the compound nucleus are discussed. The theory of the fission process and the theory of nuclear systems are omitted as special phenomena. An appendix contains a table of nuclear species giving the isotopes of the elements, their abundance, and products of disintegration.

F-M SIMPLIFIED. By M. S. Kiver. D. Van Nostrand Company, Toronto, Ontario, Canada, New York, N. Y., and London, England, 1947. 347 pages, illustrations, diagrams, charts, tables, 8½ by 5½ inches, cloth, $6. Starting from basic principles, the author develops the operating processes of frequency-modulated radio and then breaks them down into individual units of apparatus that compose the complete set. He explains how each unit works, what it does, and the characteristics of the various types. All the units then are assembled into complete installations with detailed accounts of circuit construction and full directions for aligning receivers. Many diagrams and charts are provided to illustrate the details of installation, operation, and servicing.

INDUSTRIAL ACCOUNTING, COMPLETE COURSE. By S. W. Spectbric. Prentice-Hall, New York, N. Y., 1947. 395 pages, tables, 9¼ by 6 inches, cloth, $5.35. Emphasizing the processes and executive uses of industrial accounting, this volume may be used as a text by business administrators, engineers, and engineering students. Basic accounting principles and bookkeeping procedure are discussed in the early chapters. The main features of corporation accounting then are presented, followed by a group of chapters devoted to cost accounting theory and procedure. How to use the accounting data in administering a business is stressed throughout the book, and the concluding chapters deal with the executive uses of the accounting data for the control of business expense, the measurement of the operating results, and the formation of business policies.

NATIONAL ELECTRICAL CODE HANDBOOK. By A. L. Abbott. Sixth edition. McGraw-Hill Book Company, New York, N. Y., and London, England, 1947. 633 pages, illustrations, diagrams, charts, tables, 7¼ by 4½ inches, cloth, $4. Dealing with many questions on materials, plans, wiring, and installation, this volume is a practical reference book covering the 1946 National Electrical Code. Six divisions are made. Part 1 consists of definitions. Part 2 is devoted to the 15 types of wiring for use in light and power wiring systems. Rules for installation are in part 3, while the requirements for installation, such as rules for services, grounding, automatic overcurrent protection, and wiring installation design are grouped in part 4. Part 5 deals with special cases, and all specifications for the construction of materials, devices, apparatus, and equipment are placed in part 6. Also in this section are such tables as those of simplified data applying to the wiring of motors of all ordinary types, sizes, and voltages.

PRODUCTION WITH SAFETY. By A. L. Dicki. McGraw-Hill Book Company, New York, N. Y. and London, England, 1947. 242 pages, diagrams, tables, 9¼ by 6 inches, cloth, $2.50. Accident prevention is demonstrated as a plant investment which results in substantial dollar savings. The book shows how accidents to workers, machines, and materials can be controlled, and how such control will reduce costs and increase production efficiency. The responsibility of the industrial supervisor is shown clearly, and a description of a typical safety engineer on the job illustrates the requirements of the work. Thirteen safety talks are included for use as best suits any given plant situation.

REPORT ON GERMAN BLAST FURNACE PRACTICE AND PLANT. British Iron and Steel Federation and British Iron and Steel Research Association, London, England, 1946. 57 pages, diagrams, charts, tables, 9¼ by 6½ inches, paper, 10s/6d. Prepared under the auspices of a British Intelligence Subcommittee, this volume deals with the development of German blast furnace practice and design during the war. Among the changes in processes and equipment, the progress made in the installation of plants for ore crushing and sintering is particularly noted. The changes in furnace design are discussed, as well as the progress made in the development of blower equipment, gas cleaning practice, and vortex dust catchers.

60 YEARS WITH MEN AND MACHINES, AN AUTOBIOGRAPHY. By F. H. Colvin in collaboration with D. J. Duffin. McGraw-Hill Book Company, Whittlesey House Division, New York, N. Y., and London, England, 1947. 297 pages, illustrations, diagrams, 9¼ by 6 inches, cloth, $3.50. An account of the important developments in the world of machinery from 1884 to the present day is given by a noted editor and writer of technical literature. The book is highlighted by stories of inventors, engineers, workmen, and industrialists with whom the author closely was associated. From the descriptions of early machine-shop days to discussion of current management problems, the text illustrates the industrial progress of the last 60 years.

SURVEYING, INSTRUMENTS AND METHODS FOR SURVEYS OF LIMITED EXTENT. By P. Kissam. McGraw-Hill Book Company, New York, N. Y., and London, England, 1947. 384 pages, illustrations, diagrams, charts, tables, 9¼ by 6 inches, cloth, $3.50. This textbook for short courses is designed for students in all branches of engineering. Basic surveying methods are presented fully, and the construction, theory, use, and adjustment of the transit and level are emphasized strongly. In addition to covering mapping and detailed measurements of small areas, the book also deals with the use of surveying techniques in plant layout and the establishment of dimensions of jigs and fixtures for large products.

SYMPOSIUM ON pH MEASUREMENT, 49th Annual Meeting, American Society for Testing Materials, Buffalo, N. Y., June 24–28, 1946. Technical Publication number 73. American Society for Testing Materials, 1916 Race Street, Philadelphia, Pa. 1947. 79 pages, diagrams, charts, tables, 9 by 6 inches, paper, $1.50; to ASTM members, $1.15. This compilation presents seven papers on the latest theory and practice in colorimetric and potentiometric methods for making pH and closely related measurements. The following topics are covered: historical review, the fundamentals and theoretical basis for pH determinations, recent advances in principal methods and techniques, and applications to particular fields.

TABLES OF THE BESSEL FUNCTIONS $J_0(z)$ AND $J_1(z)$ FOR COMPLEX ARGUMENTS, prepared by the mathematical tables project, National Bureau of Standards, Second edition. Columbia University Press, New York, N. Y., 1947. 403 pages, diagrams, 10⅝ by 7⅝ inches, cloth, $7.50. Presenting 10-place tables prepared by the mathematical tables project of the National Bureau of Standards, this volume covers the functions of $J_0(z)$ and $J_1(z)$ for moduli ranging from 1 to 10 at intervals of 0.01. Contour lines of $J_0(z)$ and $J_1(z)$ are given, as well as a table of Lagrangian interpolation coefficients. A bibliography containing 67 references also is included.

## PAMPHLETS • • •

**Manual of Aluminum Casting Alloys,** Prepared to be of assistance to design engineers, foundrymen, and users of castings, the book contains tabular data on physical and mechanical properties of various sand and permanent mold aluminum alloys most commonly used, general metallurgy of aluminum alloys, properties of specific alloys, foundry, practice, and heat treatment. Available without charge from the Aluminum Research Institute, 111 West Washington Street, Chicago 2, Ill.

**Soil Conservation.** A 28-page booklet giving facts about soil conservation, particularly as it applies to the State of Pennsylvania. Issued by the Pennsylvania Department of Commerce, State Planning Board, Harrisburg, Pa.

**Slide Rule Short Cuts.** A booklet written for the person who desires to improve his technique with the slide rule. Although it is directed mainly toward short cut methods which are useful to electrical engineers and radio technicians, it is said that anyone who is able to do ordinary multiplication and division on a slide rule should derive benefits from it. W. P. Miller, 536 "F" Street, San Diego 1, Calif., 16 pages, $1.50.

**Standard Welding Symbols.** A revised edition of the 1942 Symbols and earlier publications covering 34 of the processes used in various industries throughout the United States. "Standard Welding Symbols and Rules for Their Use," American Welding Society Headquarters, 33 West 39th Street, New York 18, N. Y. Price 50 cents.

**Resistance Welding Bibliography.** "Electric Resistance Welding—A Bibliography of the Literature from January 1936 to June 1947," by Harold S. Card, contains titles, authors, and publication dates of 646 articles on resistance welding subjects which have been published in 49 technical and industrial magazines during the period indicated in the title. Lists of current standards publications and books and booklets are included. Published by Harold S. Card, 850 Euclid Avenue, Cleveland 14, Ohio, 22 pages, $1.

**Tantalum.** Physical, chemical, and electrical properties of the metal tantalum are tabulated and discussed in this booklet. Comparison with better known metals are made in many instances. Workability, weldability, machinability, and fabricating techniques are discussed. "The Metal Tantalum," Fansteel Metallurgical Corporation, North Chicago, Ill. Available without charge.